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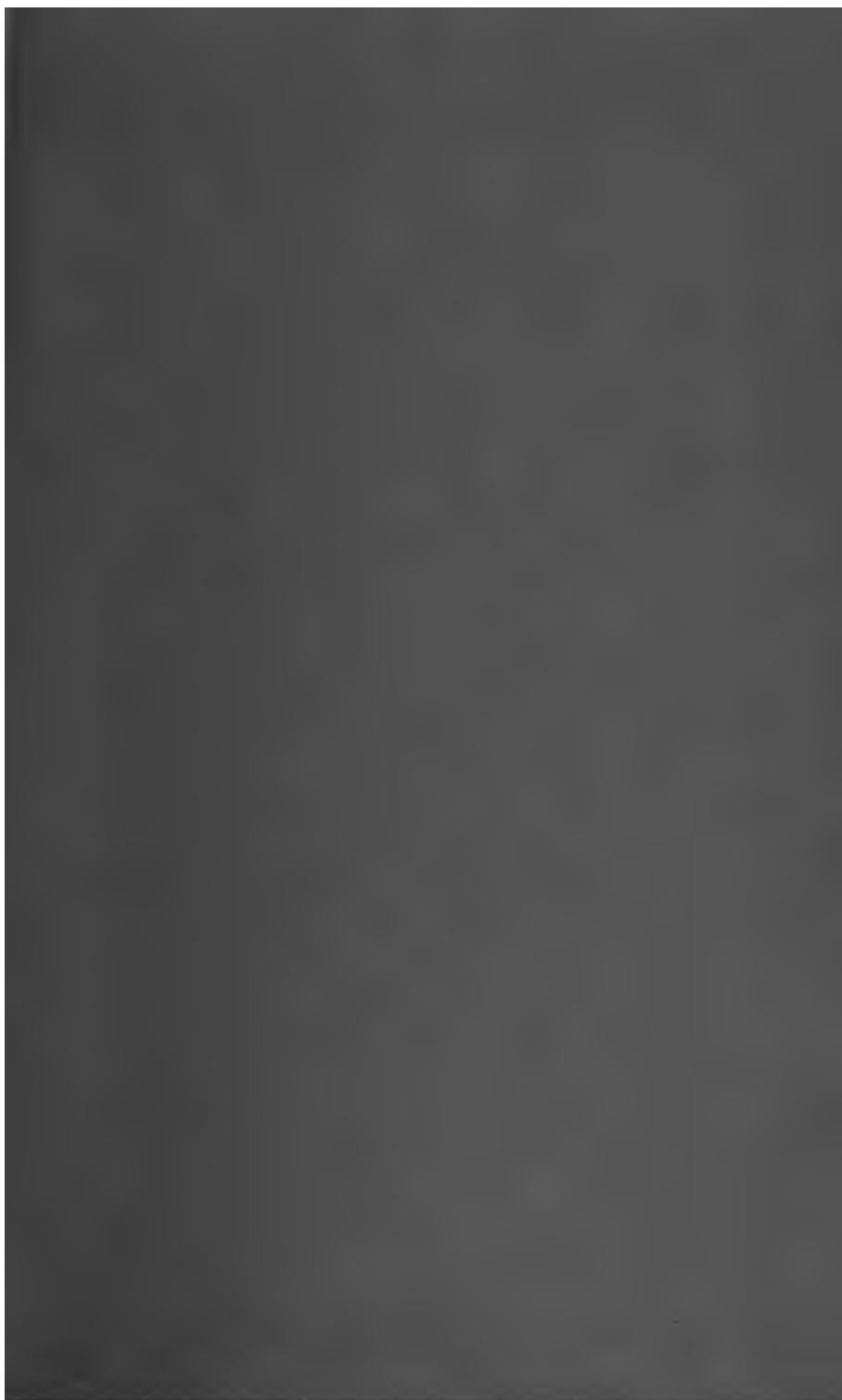
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No. I.]

[1890.

THE JOURNAL

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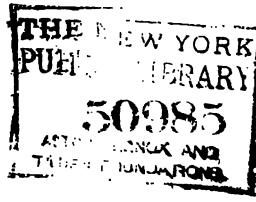
IRON AND STEEL INSTITUTE.

1890.

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PROCEEDINGS
OF THE
IRON AND STEEL INSTITUTE.

—
ANNUAL MEETING, 1890.
—

WEDNESDAY, MAY 7TH.

THE ANNUAL MEETING of the INSTITUTE was held to-day at the Institution of Civil Engineers, 25 Great George Street, London—
SIR JAMES KITSON, Bart., President, in the Chair.

The Minutes of the previous General Meeting were read, confirmed, and signed by the Chairman.

NEW MEMBERS.

Mr. JAMES JOHNSTON (Manchester) and Mr. HENRY WEBB (Bury) were appointed scrutineers of the voting-papers, and reported, on the completion of their scrutiny, that the following candidates for membership had been duly elected :—

ADAMSON, JOSEPH.....	Hyde.
ARMSTRONG, GEORGE.....	Wolverhampton.
ARROL, SIR WILLIAM.....	Bridgeton, Glasgow.
BALDWIN, STANLEY.....	Wilden, Stourport.
BILLY, EDOUARD DE.....	Paris.
COOK, THOMAS.....	Sheffield.
DEVEREUX, WALTER B.....	Colorado, U.S.A.
DIXON, SAMUEL.....	Salford.
DORÉ, SAMUEL LAMMAS.....	London.
DUDLEY, RIGHT HON. EARL OF.....	Dudley, Staffs.

ELLIS, JOSEPH.....	Workington.
GENY, MAURICE.....	Paris.
GIELGUD, HENRY.....	London.
GILMOUR, JAMES ANDERSON.....	Maryport.
HARLEY, WALTER.....	Smethwick.
HAWAH, CHARLES J.....	Philadelphia, U.S.A.
HENNIN, ALPHONSE.....	Illinois, U.S.A.
HIPKINS, WILLIAM.....	Wolverhampton.
HOLLIDAY, HENRY.....	Leeds.
HOLTZER, LOUIS.....	Unieux, France.
HUNSIKER, MILLARD.....	Pittsburgh, U.S.A.
JONES, HENRY.....	Rotherham.
LASH, HORACE W.....	Pittsburgh, U.S.A.
LIVESEY, FERNANDO HARRY WHITEHEAD.....	London.
MACFARLANE, WALTER.....	Glengarnock.
MAGERY, MAURICE.....	Rothe-Erde.
M'ANALLY, PETER.....	Philadelphia, U.S.A.
M'CONWAY, WILLIAM.....	Pittsburgh, U.S.A.
MERRITT, LOUIS GILBERT.....	Lockport, New York.
MISCHKE, CARL.....	Weitburg, Prussia.
MUIR, ALFRED.....	Manchester.
MUSGRAVE, WALTER M.....	Bolton.
NEEDHAM, CHRISTOPHER THOMAS.....	Manchester.
NORTH, COL. JOHN THOMAS.....	Eltham, Kent.
OPENSHAW, WILLIAM HENRY.....	London.
OSER, JOHANN.....	Vienna, Austria.
OSMOND, F.....	Paris.
PEACOCK, RALPH.....	Gorton, Manchester.
PERKINS, JAMES WATT.....	Brighton.
PETRE, AXEL E.....	Philadelphia, U.S.A.
PFEIFER, FERDINAND.....	Leipzig, Germany.
POLONCEAU, GUSTAVE ERNEST.....	Paris.
POWELL, JOHN.....	Landore, S. Wales.
PROCTER, JOHN R.....	Kentucky, U.S.A.
PUGH, CHARLES HENRY.....	Birmingham.
PURVES, DAVID.....	North Dulwich, S.E.
RANKINE, MATTHEW.....	Cleddens, N.B.
RENSHAW, WILLIAM ROBERT.....	Kidsgrave, Staffs.
RETZ, COMTE G. DE.....	Villerupt, France.
ROGERSON, JOHN E.....	Wolsingham.
RYDER, GEORGE.....	Tonge, near Bolton.
RYLAND, FRED.....	West Bromwich.
SALMON, WILLIAM.....	Holmrook, Carnforth.
SALTER, GEORGE.....	West Bromwich.
SANKEY, JOHN WILLIAM.....	Wolverhampton.

SAUER, FRANZ.....	London.
SCHNEIDER, CHAS. PROSPER EUGENE.....	Creusôt, France.
SHANKS, WILLIAM.....	Johnstone, N.B.
SHEFFIELD, R. S.	Woolwich.
SMITH, HARRY JOHN.....	Newmains, N.B.
SQUIRE, WILLIAM STEPHENS.....	London.
STEELE, ROBERT, JUNE.....	Dumbarton.
SYDELIUS, A. G.....	Sweden.
THOMAS, FRANCIS TREHERNE.....	Lydbrook, Ross.
TORRENS, GERARD.....	London.
WADHAM, WALTER FRANCIS AINSLIE.....	Dalton-in-Furness.
WALKER, ARTHUR TANNETT.....	Leeds.
WAWN, CHARLES.....	Wednesbury.
WHITWELL, WILLIAM FRY.....	Stockton-on-Tees.
WILD, FREDERICK CHARLES.....	Sheffield.
WILLIS, THOMAS WILKINSON.....	Sheffield.
WILSON, GEORGE.....	Broughton Grange.

The SECRETARY read the

REPORT OF THE COUNCIL FOR THE YEAR 1889.

THE Council, in presenting the 21st Annual Report to the members, have pleasure in announcing that the Institute has, during the year 1889, made perhaps as much progress, both from a numerical and from a technical point of view, as in any previous year of its history.

MEMBERSHIP.

The Institute numbered, at the end of 1888, 1355 members, which was a net increase of 42 on the number on the list at 31st December 1887. At the end of 1889 the number of members on the list was 1427, being a net increase of 72, after the losses by decease and resignation have been provided for. The number of new members proposed at the present meeting is 72, as compared with 54 candidates at the corresponding meeting in 1889. A glance at the list of candidates set down for election at the present meeting will show that a considerable proportion of them are resident out of England. That list will make an addition of 22 to the number of our foreign members. The Council, in view of the proposed meeting in the United States, refer with satisfaction to the nomination of a number of American candidates.

During the past year the following deceases of members of the Institute have taken place :—

Daniel Adamson, Manchester.	F. E. Lewis, Wolverhampton.
William Bevan, London.	C. S. Lindsay, Durham.
F. M. Bragiotti, Newcastle-on-Tyne.	John Lloyd, Birkenhead.
W. Clark, Mansfield.	T. A. Main, Sheffield.
Wm. Dalzell, Whitehaven.	John McMillan, junr., Dumbar-ton.
W. F. Dennis, London.	W. H. Müller, Dusseldorf, Ger-many.
W. Ehlers, Cartagena, Spain.	Richard Peacock, M.P., Man-chester.
Samuel Godfrey, Middlesbrough.	Charles Sacré, London.
Edwin J. Grice, Reigate.	Thomas Shanks, junr., John-stone, N.B.
Richard M. Harrison, Working-ton.	John Siltzer, London.
James Howard, London.	F. C. Stephens, Bilbao, Spain.
Thomas James, Redcar.	W. Stroudley, Brighton.
E. Jeffreys, Leeds.	John Thornton, London.
Capt. W. R. Jones, Pittsburgh, U.S.A.	W. A. Tyzack, Sheffield.
General N. Kalakoutsy, St. Petersburg.	Alan C. Wylie, Tientsin, China.

The Council desire to express their deep sense of the loss which the death of Mr. Daniel Adamson has entailed upon the Institute. Mr. Adamson was one of the original members of the Institute, and had long been one of its most active members. He contributed several papers of great value to our proceedings, and took a prominent part in the discussion of many others. Since 1873, Mr. Adamson had been a member of Council. He was elected a Vice-President in 1885, and in 1887–88 he filled the office of President with much distinction.

The only change that has occurred in the composition of the Council during the past year has been the transference of Mr. G. J. Snelus, F.R.S., to the list of Vice-Presidents, in the place of Sir James Kitson, Bart., elected President, and the election of Mr. B. Walker as an ordinary member of Council, in place of Mr. Snelus.

PAPERS READ IN 1889.

At the meetings held in London and at Paris, respectively, during 1889, the following fourteen papers were read and discussed, namely :—

At the Spring Meeting.

- On the Influence of Copper on the Tensile Strength of Steel. By Dr. BALL and Mr. ARTHUR WINGHAM.
- On Alloys of Nickel and Iron. By Mr. JAMES RILEY, Glasgow, *Member of Council.*
- On the application of Thermo-Chemistry to the Reactions of Metallurgy. By M. POURCEL, Saltburn-by-the-Sea.
- On Testing Machines in France. By M. F. GAUTIER, Paris.
- On the German Iron Industry. By Herr SCHRÖDTER, Düsseldorf.
- On Rolling Mills. By Herr HUGO SACK, Duisburg.
- On the Basic Open-hearth Process. By Mr. J. H. DARBY, Brymbo.

At the Autumn Meeting.

- Notes on the Iron and Steel Manufacture in France in 1887, and as illustrated by the French Exhibits at the Paris Exhibition. By Professor JORDAN, Paris.
- On the Proposed Channel Bridge. By M. HENRI SCHNEIDER, Creusot.
- On Gaseous Fuel. By Sir LOWTHIAN BELL, Bart., F.R.S., Middlesbrough, *Past-President.*
- On the Thomson Process of Electric Welding. By Mr. W. C. FISH, Boston, Mass.
- On a New Form of Siemens Furnace, arranged to recover Waste Gases as well as Waste Heat. By Mr. JOHN HEAD, M. Inst. C.E., London, and Mr. P. POUFF, Nevers.
- On Alloys of Iron and Silicon. By Mr. R. A. HADFIELD, Sheffield.
- On the Robert-Bessemer Process. By Mr. L. GARRISON, Philadelphia.

PARIS MEETING.

In the Report of the Council for 1888, it was announced that they had accepted an invitation from the French Society of Civil Engineers to hold the autumn meeting of 1889 in Paris. That meeting, the Council are glad to say, was in every way successful. The French Society of Civil Engineers, and the engineers and metallurgists of France generally, appeared to vie with each other in their endeavours to afford to the members of the Institute all the instruction and hospitality within their power. M. Eiffel, as President of the *Société des Ingénieurs Civils*, took a prominent part in the reception of the Insti-

tute, and in various functions in connection with which the members of the Institute were the guests of the *Société*.

The excursions which took place at the close of the meeting were rather longer than usual, but the Council cannot but feel that those who assisted at them were fully recompensed for the toil of the somewhat lengthy journeys that they involved. The Council would refer with special satisfaction to the excursion to Le Creusot, where they presented, through Sir Lowthian Bell, *Past-President*, a special Bessemer gold medal to M. Henri Schneider, in consideration of his services to the iron and steel industries of France; and to the excursion to the Loire, where the party was headed by the President of the Institute and M. Eiffel, and where an extremely cordial reception was accorded to them. The Council hope and believe that one important result of the meeting in Paris will be the establishment of a better and more fraternal relationship between the metallurgists of the two countries.

Subsequent to the meeting in Paris, the Council arranged for the presentation to Mr. Henry Chapman, to whom the success achieved on that occasion was so largely due, of a handsome silver-gilt vase of the time of George III., which was handed to Mr. Chapman by the President at a Council meeting held in November. The services of Mr. Chapman's manager in Paris, M. Vaslin, were also suitably recognised by the presentation of a silver inkstand.

THE FORTHCOMING MEETING IN THE UNITED STATES.

The members have recently been informed, by circular, of the general character of the arrangements proposed for the meeting to be held in the ensuing autumn in the United States of North America. The Council would now confine themselves to remarking that there is every prospect of that meeting being alike instructive, agreeable, and successful. A committee of reception is now at work, arranging for the several excursions that it is proposed to ask the members to undertake; and the only danger appears likely to be that these excursions will be so comprehensive as to involve the necessity of a longer stay in the United States than probably some of our prominent members can conveniently arrange for.

The Council have arranged that the autumn meeting of the Institute shall be held in New York city, and it will be followed by an international meeting, promoted jointly by the American Institute of Mining Engineers and the Iron and Steel Institute, to which leading Continental metallurgists and engineers have been invited.

The Council have not, as intimated in their circular to the members, thought fit to make any special arrangements with a view to the transport of members, as a body, across the Atlantic. Each member is expected to make his own arrangements for the voyage. The Council would, however, take this opportunity of impressing upon members who have decided to be present at the American meeting that they should lose no time in making their arrangements with the steamship companies, if they have not already done so.

DIPLOMAS FOR BESSEMER MEDALLISTS.

The Council have, during the past year, made arrangements with a view to providing diplomas for the gentlemen who have, up to the present time, been awarded the Bessemer gold medal. These diplomas, signed by the President, Sir Henry Bessemer, and the Secretary, have been forwarded to those whom the Council have from time to time deemed to be worthy of this distinction.

THE BESSEMER GOLD MEDAL FOR 1890.

The Council have decided to award the Bessemer medal for 1890 to Mr. William D. Allen, of Sheffield, in recognition of his early successful endeavours to manufacture a high quality of Bessemer steel. The Council have also resolved to award a special Bessemer gold medal, kindly provided by Sir Henry Bessemer, to Mr. Abram S. Hewitt, one of the most distinguished ironmasters in the United States. The latter medal will be presented on the occasion of our joint meeting in the United States with the American Institute of Mining Engineers, of which Mr. Hewitt is this year the President.

INDEX TO PROCEEDINGS.

The Council have ordered the preparation of a Subject-Index to the "Proceedings" of the Institute, since the date of the index issued in 1882. This new index, which is now almost completed, will be issued to members in the course of the ensuing summer, and will be carried up to the end of 1889. The Council take this opportunity of stating that the index to the "Proceedings," from the origin of the Institute in 1869 to the end of the year 1882, may still be purchased at the original price of 2s. 6d., on application at the offices of the Institute.

THE LIBRARY.

The Library of the Institute has been enriched during the past year by the addition of a considerable number of foreign metallurgical and engineering works. Members are invited to make an increased use of the Library, where they will find all the current technical publications relative to the various branches of engineering and metallurgy, in addition to most of the standard works of reference on these subjects.

STATEMENT OF ACCOUNTS.

The annual statement of accounts for the year 1889, which has been issued to the members, as usual, in advance of the annual meeting, shows that the income was £3,442, 10s. 2d., and the expenditure £2,794, 12s. 2d., leaving a balance of £647, 18s. 0d.

The retiring members of Council for 1889, as announced at the Paris meeting, are :—

Vice-Presidents.

Mr. Wm. Evans. Mr. E. P. Martin.
Mr. Wm. Jenkins.

Members of Council.

Mr. G. J. Barker. Mr. Alfred Hewlett.
Mr. W. T. Crawshay. Mr. James Riley.
Mr. G. J. Snelus.

As no other candidates have been nominated for election, these gentlemen, who are all eligible, will be re-elected members of Council.

The PRESIDENT said it was now his duty to move the adoption of the Report. He could not do so without alluding for a moment to the brilliant success of the meeting in Paris, and asking the approval by the members of the act of the Council in presenting a very handsome vase to Mr. Chapman for the services he had rendered. There could be no doubt whatever that the arrangements made by Mr. Chapman—his preliminary arrangements with the heads of the engineering and iron and steel trades in France before

the Institute went there—were really the reasons why the meeting was so successful. Not only had Mr. Chapman given his personal services, but he had placed at the disposal of the Institute his suite of offices and his own staff, and thereby the Institute had saved a very considerable amount of expense. Nor could he move the adoption the Report without alluding to the loss of their late esteemed friend and President, Mr. Daniel Adamson, who last year was seated by his side, but who had now gone from among them. Mr. Adamson was one of the men who had made England what it is—a resolute, self-educated man, who through the whole of his life was continually acquiring and developing scientific knowledge. Mr. Adamson had had vast experience in all branches of the engineering and steel industries, and it was a great satisfaction to the Council, as he was sure it would be to the members of the Institute, to know that Mr. Adamson had coveted for some time the honour of being President of the Institute, to remember that they were able to place him in that conspicuous and distinguished position, and to learn that he had had great pleasure and enjoyment in fulfilling the duties of his office. There could be no doubt that he had fulfilled those duties most admirably, and his kindness and geniality towards all the members of the Institute were unmeasured. The Council had taken care to convey that expression of their feelings, and the feelings of the members generally, to Mrs. Adamson.

He might also be permitted to refer to their anticipated visit to the United States. They hoped to have—and he believed they would have—a very large contingent. Probably three hundred members of the Institute would pass over to receive the hospitality of their friends in the States. He might mention that, when they were asked what arrangements they should have to make as to railway transport and other matters in the States, they received letters from Mr. Abram S. Hewitt, Mr. Carnegie, and Dr. Raymond, stating that, at a meeting of the Institute of Mining Engineers, and of representatives of the iron and steel trades, it was resolved, in answer to the Secretary's communication, to "offer to the Iron and Steel Institute, free of charge, excursion trains from New York to Pittsburg, and, at the close of their stay at Pittsburg, trains to Lake Superior, *via* Chicago, and to Alabama and back." There

had gone on so well of late, that some of the members might imagine that their organisation was now virtually self-acting. But long experience in the inner workings of another Institution had enabled him to state confidently that that could never be the case. Things could not go on as well as they had done, were it not that some of the ablest men sacrificed a great deal of time, trouble, and expense for the benefit of the whole body. These gentlemen well deserved the thanks of the rest. They had done remarkably well in the past; but, as the members saw, they were not yet tired of their responsibilities. In arranging a visit to the States, they were undertaking a much greater task than they had ever done before. The President had done his best to impress upon the members that they would have to make absolutely their own arrangements in regard to the voyage. He was quite certain, however, that they and their wives also would expect the Council to undertake the responsibility of bringing them safely back to their homes.

The motion was agreed to by acclamation.

The PRESIDENT said he desired on behalf of himself and the Council to thank his old friend, Mr. Carbutt, for his kindly allusions, and the members generally for their acceptance of his proposal.

THE BESSEMER GOLD MEDAL.

The PRESIDENT said he had to announce that the Council of the Iron and Steel Institute had decided to award to Mr. W. D. Allen the Bessemer gold medal for his services to the steel trade. It was widely known among the members that Mr. Allen was a most valuable coadjutor and assistant to Sir Henry Bessemer in his earlier experiments, and in conquering the difficulties which arose in the development of the Bessemer process. He was quite sure it would be more gratifying to Mr. Allen, and more instructive to the members, to hear something from one who knew distinctly what were the difficulties to be met, and what were the services which Mr. Allen had rendered, and he would therefore call on Sir Henry Bessemer to supplement the few observations which he had made.

Sir HENRY BESSEMER, F.R.S., said it would be necessary for him to go back half a century to recall his first connection with his friend Mr. Allen. At some fifteen years of age Mr. Allen came to him to learn, as far as he was able to teach him, something of practical, and also of theoretical, engineering. In different capacities of that sort, Mr. Allen served him very well until some three or four years afterwards, when he (Sir Henry Bessemer) made an invention, of which he had no doubt the members were aware, for the manufacture of bronze powder—an invention which was never patented, but was kept an absolute secret between Mr. Allen, himself, and two others for forty years. That process was in active operation at a place they had also perhaps heard of—Baxter House, St. Pancras. While engaged there he made his first attempts to improve iron, and, ultimately, to manufacture steel. Mr. Allen assisted him in those earlier experiments; he knew all that was being done before a single patent was applied for, and actively helped him in his work. They had succeeded so far as to produce a commercial article, but they found that their good friends at Sheffield had no faith in the Bessemer process, and would not have it at any price. It then became a necessity to force it upon them, and, through them, on the rest of the world. It was therefore proposed by himself, his partner, Mr. Longsdon, Messrs. Galloway of Manchester, and Mr. Allen, that they should erect a steelworks in Sheffield, so as to show what they could do, and either succeed or fail. Under those conditions Mr. Allen, whose faith never faltered from the first hour, voluntarily gave up his position with him in the bronze works, and took his chance of what they could do at Sheffield, putting his own share of capital into the partnership, and taking the position of manager of the works. At that time the works at Sheffield had no interest in the patent whatever, but they were allowed to use the patent without a royalty, and in consideration of that they were to show the process to all and sundry who wanted to come and learn what they could of the system. It fell to Mr. Allen's share to show to most of the earlier Bessemer steel manufacturers how the process was worked, and all the many little ins and outs of it. Mr. Allen never suppressed any of these in the smallest degree, as he gave all the knowledge that he himself

had acquired. In 'due time the partnership expired, and he now felt almost obliged to mention one fact that otherwise he would not care to name. When one had a managing partner who had done wonders in his way, it was only just that he should say that at the end of fourteen years, the first two having been spent almost experimentally, leaving twelve years of regular commercial working, it was found that each partner had drawn just eighty-one times the capital that he had embarked; in other words, they had on an average realised cent. per cent. every two months for twelve years, as a result of working a process that was thought to be wholly impracticable and of no use whatever. At that time, he (Sir Henry Bessemer) left the partnership, and Mr. Allen purchased the business and converted it into a joint-stock company, of which he and his three sons were the chief proprietors, and he was still working the process successfully. One thing he had done which was peculiar; he had studied chiefly to make Bessemer steel suitable for the great variety of purposes for which steel was ordinarily employed, and by his great experience and personal attention to the business, he had been enabled to make steel of a great variety of qualities, suited to many special manufactures, and had at last been able to produce steel which was now being purchased in very large quantities by manufacturers who did not generally own that they used Bessemer steel, but who fortunately did not object to pay a good price for a superior quality. He did not know that it was necessary for him to add anything further, except to express the great satisfaction which it gave him to know that the President and Council of the Institute had recognised Mr. Allen's services to the trade by which he himself had also largely benefited.

The PRESIDENT said he had now great pleasure in presenting Mr. Allen with the Bessemer gold medal on behalf of the Institute. He had also pleasure in presenting him with a diploma, which had been carefully prepared for presentation to the Bessemer Medallists by Sir Henry Bessemer himself.

The medal and diploma were then handed to Mr Allen.

Mr. W. D. ALLEN said he desired first of all to thank Sir Henry

for the very kind manner in which he had spoken of him. He felt his kindness very much, and his words had almost unnerved him in his endeavour to make an adequate acknowledgment for the distinction which he had received at their hands. He thanked the Council sincerely for the great honour they had conferred upon him, and he accepted the beautiful gold medal, and the illuminated diploma, with the greatest pleasure, and, he trusted, with a due sense of the importance and distinction they conveyed with them. During his career as a steel-maker, he did not know that he had ever received any reward, pecuniary or otherwise, that had given him so much pleasure, or that he prized so much, as this recognition of his labours by the President and Council of the Iron and Steel Institute. His labours in steel-making dated back thirty-four years. At that time, he need hardly say, their art was in a very different condition from what it was at the present time. The production of large masses of steel was then practically unknown. And the idea of producing large masses of steel, or even steel at all, by the novel, and, as it was then regarded, the wild and impracticable scheme of Sir Henry Bessemer, was ignored altogether; the world did not believe it. But although that was the case, Sir Henry Bessemer, fortunately for the world, did believe it, and stuck to his task, and by his patience and perseverance the difficulties of his process were overcome. Nowadays, there were very few persons who would not admit that by the Bessemer process large masses of steel could be made of as good quality as the steel made by any other process. The Bessemer process had had so marvellous a career, had done so much for the world, and had contributed so greatly to the material benefits and the well-being of mankind generally, that he could not help thinking that any incident, however small, connected with the earliest days of its development would be listened to and received by the members of the Institute, and, with the President's permission, he would relate one such incident. When the process was in its infancy, experiments were being made, almost in secrecy, at Baxter House, and what he was about to state, he therefore believed, was known only to Sir Henry Bessemer and himself. The very first Bessemer converter consisted of a clay crucible, similar to a steel melting-pot, except

that it had a dome lid. Round the edges of the dome were holes for the escape of the gases, and a larger hole in the centre for the admission of the tuyere. The tuyere itself was a length of $\frac{3}{4}$ -inch gaspipe with a clay nozzle at one end, and an elastic pipe connected with the air-vessel at the other. The way it was proposed to use this converter was to put the pot into a furnace sunk in the ground, similar to an ordinary steel-melting furnace, and charge it with 40 to 50 lbs. of pig iron, and, when the pig had melted, to insert the clay nozzle through the hole in the top of the lid, and blow into the molten metal until it had become steel, then to take it out, and cast it into an ingot mould in the usual way. By that apparatus they thought they were going to bring about a revolution in the steel trade. Sometimes they succeeded in making a piece of an ingot having all the characteristics of steel, but he was bound to say that their failures were more frequent than their successes. The first difficulty that cropped up on putting this apparatus to work was that they could not melt the pig iron. The fact was, the furnaces had not a good draft; they could only use ordinary gas-coke, and fire as they would, they could not get sufficient heat to melt the pig. Sir Henry was a little disappointed with this result. But on looking into the pot, he said he thought there was a small quantity melted at the bottom, and it seemed that a little had sweated out of the pig, and he directed "the nozzle to be put in, to try and convert that which was melted." Accordingly, the nozzle was inserted, and they had not blown more than half a minute before the whole of the pig was in a beautifully fluid condition. They continued blowing for seven or eight minutes, all full of anxiety as to what was going on. At last they took off the cover and looked in, and there they saw such a glorious heat in the interior of the pot—so white that the surrounding furnace and the fire were quite thrown into the shade. And they had this singular and rather extraordinary anomaly going on—the fire was actually taking heat from the crucible. The facts there demonstrated were not likely to escape the shrewd observation of a man like Sir Henry Bessemer. He saw their importance at once, and turned them to account; and from that day to the present the increase of heat occasioned by blowing cold air into the iron had been one of the most beauti-

ful features of his process. Such advances had been made in the trade since that time that it was really marvellous to look back. Yet he believed that the steel trade was only in its infancy—that we had only just entered the gate of a large field of operations, where fame and fortune could yet be won by those who liked to try it; and he urged the younger members of the Institute, following those who, in the natural course of things, would be compelled to leave them, to enter upon the work with a hearty good will, with patience, and with perseverance. If they did so, many of them would no doubt some day have the same reward, and the same pleasure, that he had enjoyed that day in receiving the Bessemer gold medal.

ABSTRACT OF PAPER ON A NEW FORM OF SIEMENS
FURNACE, ARRANGED TO RECOVER WASTE GASES
AS WELL AS WASTE HEAT.*

By JOHN HEAD, F.G.S., M. INST. C.E., LONDON,
AND
P. POUFF, INGÉNIEUR DES ARTS ET MANUFACTURES, &C., NEVERS.

BEFORE referring to the special subject of this communication, the Authors called attention very briefly to the great advance which has been made in heating and metallurgical operations, as the result of the labours of the late Sir William Siemens and of Mr. Frederick Siemens in connection with the regenerative gas furnace.

They referred to the first idea of applying the regenerative principle to air engines made by the Rev. Robert Stirling and his brother, James Stirling, in 1817, who also foresaw the possibility of applying the regenerative principle to metallurgical furnaces, and also to the later proposals of Mr. J. Slater in 1837 and of Mr. R. Laming in 1847.

By the light of present knowledge, it is clear that none of these proposals were susceptible of useful application without considerable modification, and there is no evidence of any application of these furnaces having been made before the Siemens furnace was introduced; and hence Mr. Frederick Siemens and the late Sir William Siemens will ever be regarded as the true inventors of the regenerative gas furnace. They were the first to heat the gas as well as the air supplied to a furnace, utilising its waste heat for that purpose, and to provide for reversing the direction of the flame in the furnace chamber whereby uniformity of heat and the highest temperatures are attained. They thus rendered possible the carrying out of processes which, until the introduction of their furnace, had only been foreshadowed by chemical research.

* This paper was read in full at the Paris Meeting, September 1889, and published in the *Journal*, No. II., of that year. The discussion was, however, adjourned to the London Meeting of 1890.

In considering the details of construction of this ingenious apparatus, it occurred to Mr. E. Biedermann and Mr. E. W. Harvey, who are on Mr. Frederick Siemens' technical staff (the former having entered the service of the late Sir William Siemens about thirty-four years ago), that possibly further economy in fuel might be realised by a rearrangement of some of the parts of the regenerative gas furnace.

In a gas producer the production of carbonic oxide is effected in two operations; on the grate hot carbonic acid is formed, in the ordinary course of combustion, which is afterwards converted into carbonic oxide whilst passing through the incandescent fuel in the upper portion of the producer, and in that condition flows on to the furnace with the other gases distilled from the coal during the process of gasification; the production of carbonic acid on the grate of the gas producer is attended with the development of heat, but its conversion into carbonic oxide is carried on at the expense of heat.

In the new Siemens furnace, a portion of the products of combustion, from the heating chamber, are delivered under the grate of the producer, which gases consisting of intensely heated carbonic acid, nitrogen, and water in the gaseous state, the production of carbonic acid in the producer may be dispensed with; but in this case the heat attending the production of carbonic acid in the producer has also to be dispensed with. It had, therefore, to be ascertained whether the products of combustion from the heating chamber would contain a sufficient amount of heat for ensuring their conversion into combustible gases, and this has been found to be the case in practice with furnaces working regularly for the past twelve months. The economy of fuel resulting from the conversion of carbonic acid into carbonic oxide is diagrammatically illustrated by means of the accompanying sketch (Fig. 1) of a gas producer. Assuming that the producer contains only coke in the incandescent state, this coke if fed with oxygen will produce carbonic acid in the lower zone, which will be converted into carbonic oxide in the upper zone; but if fed with hot carbonic acid, instead of oxygen, one-half the fuel, comprising the lower zone, may be dispensed with, and an economy in weight of fuel to the same extent will be realised.

In the new Siemens furnace the waste gases are directed, partly through an air regenerator, and partly under the grate of the producer, there to be reconverted into combustible gases, and to do the work of distilling hydro-carbons from the coal; in fact, the gas producer in this case absorbs or utilises the heat formerly deposited in the gas regenerators of furnaces; and in doing this transforms spent gases into combustible gases. It is held as an axiom—and the construction of the new furnace is based upon this consideration—that, besides air regenerators, gas regenerators, or their equivalent in the form of a converter producer, must be provided for absorbing all the heat contained in the gases leaving the furnace chamber. In the converter, the fuel absorbs the waste heat from a portion of the products of combustion leaving the furnace, and at the same time carbonic acid and water-vapour are converted into carbonic oxide and hydrogen. The annexed diagrams (Figs. 2 and 3) show the relation which exists between the ordinary and the new type of Siemens furnace. As will be seen by examining them, the function in both is the same. In the first case, the waste gases are partly directed through two regenerators, while in the second case the waste gases are partly directed through an air regenerator and partly through a converter producer. In both cases the waste heat from the furnace is entirely utilised, and the gas and air reach the furnace in an intensely heated condition. In both cases, again, there is a reversal of the direction of the flame in the furnace, which ensures uniform heating of the furnace chamber and of the materials contained in it.

This furnace may be constructed in various forms, of which one is shown in the accompanying diagrams (Figs. 4–8).

The *modus operandi* of the furnace is as follows:—Gas from the converter B passes through the flue C' and the valve D' to the gas-port G', and into the combustion chamber *h' g'*. Air for combustion passes through the regenerator A', the air-flue K', and the air-port H' into the combustion chamber, where it meets the gas from the converter, and combustion ensues. The horse-shoe flame sweeps round the heating chamber E, the products of combustion passing away by the second combustion chamber *h, g*, and going partly through the regenerator A, and reversing valve

J into the chimney-flue, and partly down the flue G, whence they are drawn by means of the steam jet I through the capped inlet under the grates NN' of the producer B, there to be converted into combustible gases. From time to time the direction of the flame in the furnace is reversed by manipulating the rocking beam, carrying the valves DD, and the reversing valve J in the usual manner of working regenerative gas furnaces. An auxiliary steam jet is provided for the purpose of supplying atmospheric air to start the producer, when the furnace is first heated up.

The new form of regenerative gas furnace has been applied in this country to the heating and welding of iron, to which uses its application is being extended in England and abroad, whilst furnaces are in course of construction to apply it for puddling iron, and for copper and steel melting. At the time this paper was written there were two furnaces at work and ten in course of erection; there are now altogether thirteen furnaces at work for heating iron and steel, in addition to fifteen furnaces for these purposes in course of construction.

The first furnace of this kind was constructed at the Pather Iron and Steel Company's Works at Wishaw for welding iron, and the results of working during the past twelve months have shown an average saving of 5 per cent. in waste on the weight of the iron heated, and a saving of upwards of two-thirds of the weight of coal used, and a greater money-saving, owing to the inferior quality of the fuel employed as compared with that used in their other furnaces fired with solid fuel. From the total saving thus realised some allowance should, however, be made for raising steam in boilers fired independently of this furnace.

This new furnace has also been recently applied for heating billets by the United Horse-Shoe Company, of London; and in this case the results are quite as satisfactory, or even better, than those just given, as shown by tables of working and analyses of the gas produced given in the original papers.

In conclusion, the following advantages may be claimed for the new furnace as compared with solid-fuel furnaces used for heating and welding iron, viz. :—A saving in fuel, amounting to, say, two-thirds in weight, and after allowing for raising steam in separate

boilers, this saving is fully equal to 5 cwt. of coal per ton of iron heated; a reduction in the waste of iron equal to 5 per cent. upon the weight of metal heated; a saving in labour and repairs which will probably compensate for the extra cost of the new furnace.

Taking a furnace to heat 10 tons of iron per shift, or 110 tons per week, the following calculation gives the money saving realised by the adoption of the new furnace:—

110 tons iron at 5 cwt. per ton = $27\frac{1}{2}$ tons coals saved at 6s.	£8 5 0
110 „ „ at 5 per cent. = $5\frac{1}{2}$ tons iron at £4	22 0 0
Being	£30 5 0

per week, or, say, £1500 per annum.

Comparative Statement showing the Working of "Coal-fired" and New Siemens Puddling Furnaces.

	"Coal-fired" Furnace (Single Puddling) during 10 Shifts.	New Siemens Gas Furnace (Double Puddling) during 7 Shifts.
	Cwts. qrs. lbs.	Cwts. qrs. lbs.
Pig metal charged	346 0 20	454 1 1
Yield of puddled bars	323 0 13	445 1 24
Loss of metal	18 0 7	8 3 4
	= 5·2 per cent.	= 1·9 per cent.
Scrap balls (bars) made	14 3 10	37 0 2
Yield of iron per shift	34 1 5	71 1 19
Coal used (including lighting up)	410 0 0	149 1 0
Coal used (including lighting up) per ton of iron made	23 3 9	6 0 22
Coal used per ton of iron made (exclusive of lighting up)	22 2 26	5 2 7
Cost of coal per ton of iron made (exclusive of lighting up)	s. d. 6 9	s. d. 2 4
	Cwts. qrs. lbs.	Cwts. qrs. lbs.
Fettling used	110 0 0	66 3 0
Fettling used per ton of puddled bars	6 2 2	3 0 0
	s. d. 3 11	s. d. 2 2
Cost of fettling per ton of puddled bars	15 0	Estimd. at 5s.
Cost of repairs per week		

The mixture of pig iron used was the same in both furnaces, and the puddled iron made in the gas-furnace is distinctly superior

to that made in the coal-furnace, the rolled bars being cleaner and more free from rough edges.

April 1890.

STEEL HEATING.

Glasgow Iron Company, Wishaw, N.B.

	Tons.	cwts.	qrs.	lbs.
Blooms from hammer heated during three shifts (36 hours)	204	10	0	0
Coal used during three shifts (36 hours)	10	10	0	0
Coal used per ton of steel blooms heated	0	1	0	3
Coal used per ton of steel blooms heated in grate-furnaces doing the same work	0	4	0	0
TRIAL CHARGE.				
Cold ingots heated during one charge of 2½ hours	17	10	0	0
Coal used during one charge of 2½ hours	0	17	0	0
Coal used per ton of steel ingots heated	0	0	3	2½
Coal used per ton of steel ingots heated in grate-furnaces doing the same work	0	7	0	0

It is assumed from the above trial charge that, working on cold ingots alone, the furnace could heat three charges, or 52½ tons per shift, with a consumption of 3½ tons of coal, *i.e.*, under 1½ cwts. per ton. This result compares favourably with 6½ to 7 tons of coal consumed in heating two charges, or 18 tons per shift, in grate-furnaces or 7½ cwts. of coal per ton of steel ingots heated.

June 1890.

DISCUSSION.

The SECRETARY then read the following communication by Professor Richard Åkerman on the foregoing paper :—

CALCULATIONS CONCERNING THE POSSIBILITY OF REGENERATING
THE GAS IN THE NEW SIEMENS FURNACE.

The interesting paper of Mr. John Head and M. P. Pouff on the new Siemens furnace has prompted me to undertake some calculations upon the possibility of working that furnace on the method designed, and I beg leave to communicate the results.

It ought to be first observed that the ratio between the respective kinds of gases of which the producer gas is composed, under similar action and using identical material, must be approximately the same in the new as in the older Siemens furnace. To understand this we only require to consider that the combustion of carbon to carbonic oxide consumes exactly the same quantity of air as the carbonic oxide thus formed requires for its further combustion to carbonic acid. Carbonic acid formed from air is, in other words, mixed with twice as much nitrogen and hydrogen as the carbonic oxide produced by means of air, by which further combustion the said carbonic acid is obtained. When next this carbonic acid, passing through sufficiently hot carbon, is converted into carbonic oxide, an equal amount of carbon to that previously present in the carbonic acid is absorbed, and at the same time the volume is doubled. And since the carbonic acid, as we have seen, brought along with it twice as much atmospheric air as would have been necessary for an equal amount of carbon as carbonic oxide, there is present with the carbonic oxide produced in this manner exactly the same proportion of nitrogen and hydrogen introduced with the air as if the carbonic oxide had been produced by the direct action of air upon carbon.

We have yet only shown that the ratio between the carbonic oxide and the nitrogen and hydrogen introduced by the air is alike, whether the carbonic oxide be produced direct with air or by the method now proposed. But the ratio of these to the other gases generated by the same fuel, such as hydrogen and hydro-

carbons, must in both cases be the same, because the amount of carbon consumed in the producer by means of carbonic acid is, as mentioned, always equal to the quantity of carbon present in that carbonic acid, and each of these carbon units is naturally accompanied by the same amount of gaseous matters, the quantity of which depends on the kind of fuel used.

The ratio between the different kinds of gas is not altered if, per unit of carbon, there is introduced with the air of combustion into the old producer, or with the combustion products into the new, an equal amount of steam; the alteration in the composition of the gases caused by the introduction of steam is equal in both cases, and consists only of a decrease of the nitrogen and an increase of the hydrogen, the combustion products reconveyed to the producer containing as much water formed by the combustion of the gases in the furnace chamber as that introduced into the producer by the injector, and at the doubling of the amount of carbon in the gas which takes place in the producer there is also a doubling of the amount of hydrogen. The single difference is that the furnace gases also contain the water got by combustion of the hydrogen of the coals.

From what has been said above, it follows that if, after being started, the process can be carried on so that no carbon is burned with air in the producer, there must, for every unit of carbon consumed from coals poor in hydrogen, be produced about twice the amount both of carbonic oxide and other gases from the new producer with combustion products as when the combustion proceeds with air, or with a corresponding mixture of air and steam. Hence it follows that, the temperature of the gases being equal, the amount of heat evolved by them in the furnace chamber per unit of carbon burned by the new arrangement must be twice as large as with the old. That is to say, on the previous assumption, the fuel consumpt for unchanged heat requirement in the furnace chamber under the former method will be reduced to half under the new, against what would be used with the old Siemens arrangement, and air forced in a similar manner by a steam injector.

In order that this may be possible, it is, however, necessary that the producer gets heat sufficient not only to replace that of which the departing gases rob it, but also the whole of

that considerable amount of heat absorbed by the burning of the carbon with carbonic acid and water vapour. We shall now try to investigate how these can be attained, and for simplification of the question, *the effects of the steam introduced by the injector is at present set aside.*

First, concerning the temperature of the gases leaving the producer when coal is the fuel, there is no reason to assume it to be different from that of other coal-gas producers without special introduction of steam, and it is commonly about 600°C . When, further, the amount of carbonic oxide obtained per unit of carbon consumed in the producer is twice as great as that obtained in an ordinary gas producer, the amount of heat carried away by the gases per unit of carbon can be approximately estimated thus: $600 \times [4.66^* + 9^{\dagger}] \times 0.244 = 2000$ calories.

The heat consumption in the reduction of carbonic acid to carbonic oxide per weight-unit of carbon is $2473 - (2.33 \times 2403) = -3126$ calories,—the calories produced by one weight-unit of carbon in burning to carbonic oxide being represented by 2473; whereas, at the same time, as much heat is absorbed as is obtained when the carbonic oxide got from 1 weight-unit of carbon $(12 + 16) : 12 = 2.33$ weight-units are oxidised to carbonic acid, namely, 2.33×2403 calories.

The requisite heat per weight-unit of carbon consumed in the producer may be thus approximately estimated at $2000 + 3126 = 5126$ calories; and if this gas regenerating process should be possible in the manner assumed, this amount of heat must be introduced into the producer by that portion of the combustion products from the furnace which is passed through the producer.

These gases under the presuppositions amount to $(12 + 32) : 12 + 9 = 12.67$ weight-units. Calculating the temperature these gases must have in order to convey to the producer the necessary 5126 calories, we find it to be $5126 : (12.67 \times 0.24) = 1687^{\circ}\text{C}$., which may be quite proper for the gases leaving the open-hearth furnace during the latter portion of the process, but surely too high during the time when melting is going on, particularly when regard is had to the cooling the gases undergo in passing

* This figure denotes the amount of carbonic oxide evolved per unit of carbon; thus $2(12 + 16) : 12 = 4.66$.

† This figure may approximately represent the amount of other gases when coals poor in hydrogen are employed and steam is not introduced into the producer.

from the Siemens furnace chamber to the producer. Add to this, that no regard has been paid in this calculation to the losses of heat, more difficult to arrive at, which necessarily take place through the walls of the producer. It must be assumed that if the specific heats used above were trustworthy, the gas generation in the new producer will not exclusively take place in the manner assumed; along with the carbonic acid some free oxygen must also be introduced in order to increase the heat by the combustion of carbon to carbonic acid.

Such an increase of heat does take place in most cases, even if it may be possible in an open-hearth furnace to obtain complete combustion of the gases without using an excess of air. The combustion products in by far the most cases contain some free oxygen from unconsumed air, which mingles with the nitrogen and carbonic acid in the combustion products, and causes in the producer a combustion of carbon not touched by the above calculation. The greater the consumption of carbon is in this way, the more the total consumption increases over the 50 per cent. obtained by the previous calculations.

The loss of heat through the producer walls is reasonably constant per unit of time for the same class of producer, and decreases consequently per unit of carbon consumed when the driving is faster; but if the latter is not too slow, 5 per cent. of the heat resources of the producer may in similar calculations be considered as lost through the walls. This, I think, in most cases approximately corresponds to the loss in gas producers using blast. In regard to the cooling of the combustion products while being led to the producer, especially when the heat lost with the ash is included, the estimate of the loss per cent. in this case ought to be increased to 8 or perhaps to 10 per cent. Assuming 8 per cent., the loss in question per unit of carbon consumed in the producer by means of carbonic acid amounts to $0.08 \times 5126 = 410$ calories, to replace which a further carbon consumption is needed of $410 : 2473 = 0.17$ weight-units, so that the whole carbon consumption will be 1.17 against 2 weights of carbon in the common producer; corresponding to an economy of carbon of 42 per cent., against 50 per cent. when extra carbon is not required to be burned with free oxygen.

A troublesome condition is that in these, as in all similar calculations, much insecurity is caused by the uncertainty con-

cerning the specific heat of these gases at high temperatures. The errors caused by this in the above calculations tend, however, to give less advantageous results for the new producer than is its due. According to Mallard and Le Chatelier,* the specific heat of carbonic acid at constant volume is so considerably increased at high temperatures that at 1800°C . it is nearly twice as much as at 0°C ., and the specific heat of the nitrogen and carbonic oxide so increases with temperature, that at 2000°C . M. M. Mallard and Le Chatelier consider it to be half as much more as at 0°C . The specific heat for ordinary temperatures is estimated for nitrogen and carbonic oxide at 0.244, and for carbonic acid at 0.217. When the above combustion products are assumed to consist of 3.66 parts carbonic acid and 9 parts nitrogen, &c., accepting the specific heat of nitrogen to be 0.244, the specific heat of this mixture should be at least: $(9 \times 0.244 + 3.66 \times 0.217) : 12.66 = 0.236$.

This figure has certainly in the above calculations been rounded off to 0.24, but this inconsiderable increase is a small matter compared with the reality, for instead of 0.24 when 1800°C ., about 0.34 would have to be used if the determinations by Mallard and Le Chatelier be correct. At the same time the specific heat of nitrogen and carbonic oxide at 600°C . should be about 0.28 instead of 0.244 as assumed above.

When the values used above for the respective specific heats 0.244 and 0.24 are replaced by 0.28 and 0.34, or instead of the latter, yet more accurately for the prevailing temperature, an intermediate specific heat 0.32 as between 0.24 for 100°C ., and 0.34 for 1800°C ., on the one side the heat consumption is increased, the gases leaving the producer containing $13.66 \times 600 \times 0.28 = 2295$ calories instead of 2000, and the sum-total of the heat required by the producer will thus be $2295 + 3126 + 410 = 5831$ calories. But, on the other side, there would only be required for this increased amount of heat a temperature of the combustion products when led into the producer of $5831 : (12.66 \times 0.34) = 1355^{\circ}\text{C}$.

Further, since the average temperature of the combustion products from an open-hearth furnace is considerably higher, it follows that in reality the activity of the gas regenerating process can take place in the first assumed manner, or without any burning

* *Comptes Rendus*, 1881, T. xciii. p. 1015.

of carbon by free oxygen, even if the respective coefficients of the specific heats are not quite so advantageous for this process as presupposed in the latter case.

All this, meantime, is valid only on the supposition made at the beginning of the calculations, that no vapour of water other than that in the air is introduced into the producer, but as in reality the new arrangement requires a steam injector to withdraw the combustion products from the furnace chamber and force them into the producer, there must be added the necessary heat required for the steam raising, and for the replacing the heat consumed by the decomposition of the water in the producer, which for every unit of carbon consumed by steam amounts to about 2360 calories. This last-mentioned heat consumption is, however, not so important, the thermal effect of the gas being improved in a corresponding degree; no loss is then sustained by admitting air into the producer, so as to expend as much carbon as corresponds to the gas improvement obtained by the decomposition of the water. It should be borne in mind that, as pointed out above, at least not any considerable part of this gas improvement can be made, so to say, for nothing, or only at the expense of available excess heat of the producer, and it is therefore only in comparison with such producers formerly used, in which only a small quantity of steam was introduced, that the fuel consumption of the new producer can be brought down 50 per cent. *plus* that required for steam production.

In comparison with such older producers as Wilson's and others, in which the air for combustion is introduced by means of a steam injector, the economy of fuel with the new arrangement becomes smaller without question in the same ratio, as the fuel consumed in them is less than in the gas producer with which steam injectors are not used; and it is only in comparison with common draught furnaces with solid fuel, still often used in countries rich in cheap coals, that such an economy can be possible as that stated by Messrs. Head and Pouff, namely, a reduction of two-thirds. But it is, of course, not with such, but with Siemens furnaces, that comparison should be made; and it is very fair if, besides the fuel necessary for the steam injector, 50 per cent. can be saved from the usual Siemens furnace consumption by the new arrangement.

Sir LOWTHIAN BELL, Bart., F.R.S., said it would be remembered by those who were present at the meeting in Paris last year, that there was a discussion on a question that had lately agitated the public mind a good deal—that of water-gas. Many of the principles involved in the consideration of that question necessarily cropped up on the present occasion; but in the paper that had just been read, and in the observations of Professor Åkerman, there were none of the errors which, as he (Sir Lowthian) conceived, ran through the whole scheme of the use of water-gas. He had endeavoured to show that it was impossible so to treat fuel as to get from it, by any difference in the manipulation, a greater amount of heat than the fuel directly applied could afford. He had been rather taken to task by the projectors of the so-called manufacture of water-gas, and he was invited to go on some future occasion to Leeds, in order to have his heresy, in not agreeing with them in that particular question, put at rest. From that time, however, to the present he had not received a renewal of that invitation to Leeds, but he was invited to go almost to the other side of Europe in order to be convinced that he was entirely in error, and to discover that there was a notable economy in the application of coal in the form of water-gas. As he had said, there was no such heresy in the paper by Mr. Head. They had all heard the figures read, but they were very difficult to follow. He had had some experience in calculations of the kind, and he knew how wearisome it was to listen to them. He would simply point out the fact that heat was now recognised as a form of motion, and that the one could be converted into the other with perfect ease. The value of coal as a means of motion, as was well known, had been ascertained with almost mathematical exactness by a man whom they had unfortunately lost a year ago, Dr. Joule. It was easy to illustrate what would follow by any attempt to get more motion out of heat than that heat was capable of affording. They might conceive a thread put over a pulley which moved absolutely without friction, and a pound weight on each side of it. It was clear that those two weights would be in a condition of static equilibrium, and that no motion would ensue; if, however, they were to put a small weight upon one side, motion would

follow, if it were enough to overcome the *vis inertia* of the mass; but it merely ensued because energy—known as the energy of position—had been made to help it; in other words, the operator, by lifting a small weight from the ground (which in fact was the result of the heat created in his own body by the food he had taken), lifted the small mass and placed it on one side of the pulley, and then motion ensued. So they had to deal with what was equivalent to friction in the combustion of fuel; namely, loss from the apparatus employed for what was called convection, radiation, and so forth.

He merely used that illustration to show how hopeless it was to expect to obtain heat without expending heat, and, as he had said, that expenditure must be greater than the heat so obtained. The conversion of one unit of carbon from its condition of carbonic oxide to carbonic acid was represented by 5600 thermal units; but it could not be supposed that, having carbonic acid on one hand, and applying 5600 thermal units, they were going to split it up so as to get back carbonic oxide. They must apply a good deal more, which was, of course, always a considerable source of waste. Mr. Head did not pretend—he knew much better than to pretend—to create heat out of nothing, but he used heat which might otherwise be wasted. He (Sir Lowthian), of course, knew very well that usually that heat was not wasted. In the ordinary puddling or mill-furnace, that heat was generally utilised in raising steam for the engines. If such heat had to be utilised, there was probably no plan more efficacious for getting the best value of the heat, otherwise wasted, than by using it for raising steam. Mr. Head had told them that he saved 5 per cent. of the waste in iron. Speaking from recollection of olden times, in heating ordinary malleable iron, the loss was nearer 10 per cent. If Mr. Head could do it for 5 per cent., there was a clear gain of half the loss, and undoubtedly that was a matter of considerable value. But it was not to be supposed that the regenerative furnace *per se* enabled one necessarily to save iron. It was quite a mistake to suppose that, because they were dealing with gas, they were not dealing with an enemy which wasted iron or steel in some way or another. It was not always free air that oxidised iron; carbonic acid

contained in the products of combustion was also a source of waste, and whether that carbonic acid was got by combustion of coal direct or by the combustion of carbonic oxide made no matter.

At the Barrow Works, coal, not gas, was used for heating steel ingots, and with less coal than they used when employing the Siemens furnace, they had no more waste. If Mr. Head had no use to which he could put the waste heat of his particular furnace, he did well by using it to regenerate carbonic oxide from his carbonic acid, and possibly that might be found profitable. He confessed he should be a little surprised if the saving was quite that which Mr. Head had said; he would not for a moment say that it might not be so, but he could hardly believe that there was such a saving in waste as Mr. Head supposed. It had been within his own experience to observe many times that a new process, whatever it might be, when it was being watched with the lynx-eye of a Mr. Head was successful, but the expected results were not entirely realised in the future. He should be glad to know what account Mr. Head could give of his furnace after he had had it in operation two or three years.

Mr. E. A. COWPER said that it seemed to him to be an extremely ingenious method of carrying the fuel to the furnace where it was to be burnt, for the incombustible hot carbonic acid sent into the ashpit, and thence through the fire in the gas producer, acted as a *carrier*, and took up its load of carbon, thus becoming converted into carbonic oxide, an inflammable gas, which, on mixing with air in the chamber of the furnace, took up oxygen (thus producing heat), and again became carbonic acid. The total quantity of carbonic acid was greater than before in consequence of the carbon taken up, the oxygen taken up, and also the addition of all the nitrogen that accompanied the oxygen in the air used; therefore a portion had to be released and passed through the regenerator to the chimney, whilst the remainder was again used as the *carrier*.

Thus one atom of carbon was carried over (and burnt in the furnace) by another atom that passed away as soon as it had

performed its duty, such second atom being in the carbonic acid that was returned to the producer for the express purpose of *carrying*.

This operation had to be contrasted with the old mode, when *two atoms* of carbon had to be sent over from the producer (that is, two atoms of fuel had to be burnt) in order to have *one burnt* in the furnace. A very simple way of putting the matter would be to suppose a number of faggots had to be put on a fire, one after another. One man could do it. But on the old plan there would have to be a man to every faggot, and after they had put them on, they would be of no further use.

It was perfectly self-evident that the waste heat from the furnace described by Mr. Head could be utilised under boilers.

He thought the invention so ingenious as to be well worthy of the school of Sir W. Siemens and his successors, and he had no doubt that very large economy would result from it, particularly where high temperatures were used.

A MEMBER asked if the table referred to by Mr. Head would be printed in the Proceedings? It appeared to him to be new material. He also wished to ask whether the coal which was used in the regenerative furnace was of the same quality as that used in the ordinary furnace? There appeared to be a marked difference in the quantity of coal used, all showing a difference in the result of the working of the two furnaces.

The PRESIDENT said that at his works they were using the Siemens regenerative furnace somewhat extensively for the heating of iron. With regard to Sir Lowthian Bell's criticism as to the waste of iron, he might mention that, according to his experience, there was in the Siemens regenerative furnace a considerable saving. He thought that about 3 per cent. on twice-heated iron was quite a reasonable and fair percentage to credit the Siemens furnace with; and it would be observed that where they were heating high qualities of iron, that saving of 3 per cent. in the value of iron was quite equal to the whole value of the fuel used in the process. If they could once assure themselves that there was that saving in iron, the saving in the percentage
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of fuel became a matter of less importance. In the experience gained at Monkbridge during the last twelve years in the heating of iron plates by the Siemens regenerative furnace they found a saving of not less than $2\frac{1}{2}$ or 3 per cent.

Mr. EDWARD P. MARTIN said he thought the President and Sir Lowthian Bell were both right. If they wanted a machine to raise a very high temperature indeed, there was nothing like the Siemens furnace, and in the same degree, if they wanted to weld iron, they had in the Siemens furnace an admirable tool; but if they used that tool simply to heat rail ingots to the temperature at which they were rolled off, he thought that the old heating furnace, using the waste heat for raising steam, gave far greater advantages.

Mr. JOHN HEAD, in reply, said that the question of raising steam with the waste heat of furnaces, in which the past-President, Sir Lowthian Bell, and many members took an interest, was one that had not escaped his attention. But he had had great difficulty in obtaining reliable information as to the amount of water evaporated in boilers attached to heating and puddling furnaces, as compared to the weight of fuel consumed in them. When he was in Sheffield a few weeks ago, however, he called on his friend Mr. R. Heber Radford (the well-known consulting engineer of that town), who told him that he had been engaged to make as accurate an estimate as possible of the evaporative power of coal after it had done furnace work. These experiments extended over several days, if not weeks. He took the evaporative power during one hour each time he went to the works, and found that the results varied considerably, but the mean of those results showed an evaporative power of 2.85 pounds of water per pound of coal consumed. The experiments were not made with one puddling furnace only, but with four, making 40 tons of iron per week. The consumption of coal was 24 cwt. per ton of iron. He (Mr. Head) therefore argued that 40 tons a week would require 48 tons of coal, which weight of coal would evaporate 137 tons of water. With the new Siemens furnace the consumption of coal per ton of iron puddled should not exceed 6 cwt., and it was well known that in firing independent

boilers with coal, an evaporation of 8 pounds of water per pound of coal was easily obtained. Hence, to puddle 40 tons of iron, and evaporate 137 tons of water, there would be required—

$$\begin{array}{rcl} 40 \times 6 \text{ cwt.} & = & 12 \text{ tons.} \\ 137 \div 8 & = & 17 \text{ tons.} \end{array}$$

Total 29 tons of coal,

as compared with 48 tons with grate furnaces fitted with boilers, being a saving of 19 tons per week, or an economy of 40 per cent., which could be attributed to the new furnace. From abroad he had heard that the weight of water evaporated with the waste heat of furnaces, did not exceed 3 pounds per pound of coal consumed, which information agreed with that he had obtained at Sheffield.

With regard to the Barrow Works, the heating furnaces referred to by Sir Lowthian Bell were of the original Siemens type, not of the new type, and he claimed that the latter saved one-half, if not two-thirds, of the fuel consumed in the former, so that the results at those works were not applicable to the new form of Siemens furnace. The oxidation of metal was a point which required careful attention in working furnaces; it depended entirely upon how furnaces were constructed and worked. He quite agreed with Sir Lowthian Bell that as much metal might be wasted in the Siemens as in the ordinary grate furnace—sometimes more. The flame coming in contact with the metal caused red-shortness in the case of steel, and oxidation in the case of iron, but that source of loss was avoided in properly-constructed Siemens furnaces. In such furnaces, a saving of 5 or 6 per cent. of metal was realised, and he (Mr. Head) was pleased to hear that the President, Sir James Kitson, had found a saving of fully 3 per cent. in working his Siemens furnaces, which were built twelve years ago. In puddling with the new Siemens furnace, a saving of rather more than 3 per cent. of iron had been obtained, the mixture of iron used being exactly the same in this as in the ordinary grate furnace, to which its working had been compared, as shown in the new table prepared for that meeting. There was also in the puddling furnace an improvement in the quality of the iron made. The iron was much more free from roughness on the edges than in the case of iron puddled in grate furnaces. A question had been

asked about the cost of coal used in the new Siemens puddling furnace. The table to which he had referred answered that question, and would be printed, with the permission of the President, as an addendum to his paper. It showed that in the new Siemens furnace the cost of the coal was 2s. 4d., and in grate furnaces 6s. 9d. per ton of iron puddled, the actual saving being over 65 per cent., which would probably be reduced to 40 per cent. by making allowance for boilers to be fired independently of the furnaces. To this saving in fuel should be added the saving in the cost of fettling used, which at Pather was found to be 1s. 9d. per ton of iron made, and the economy of 3 per cent. of iron saved upon the waste of metal.

As regards labour, considering the reduced amount of coal used in the new form of Siemens furnace as compared with grate furnaces, and remembering that the producer adjoined the furnace, there was no reason why the man attending to it should think himself imposed upon if he was asked to put in one-fourth of the amount of fuel that he would be required to use in an ordinary puddling furnace. But separate men were employed at Pather, the proprietors relieving the puddlers from the work of firing, in order that they might give their undivided attention to their metal. In that way better iron was perhaps produced, and as one producer-man attended to several furnaces, the additional expense on this account was found to be exceedingly small.

Sir BERNHARD SAMUELSON, Bart., M.P., asked what was the total cost of the puddling furnace?

Mr. HEAD said that the cost of building the double-puddling furnace at Pather was £300. With regard to Professor Åkerman's able paper, it was most interesting, and he had read it with great pleasure. He might say that he had not made any calculations of the economy which could be effected by the use of the new furnace, for the reason that, as the specific heats of gases at high temperature were not yet fixed, all such calculations would necessarily be speculative. Professor Åkerman admitted this, but, notwithstanding, feeling an interest in considering the matter from a scientific point of view, with the data at present available, he

had made some calculations, which, with the explanations he (Mr. Head) now proposed to give, would be seen to agree closely with the results of practice in working the new form of Siemens furnace. Speaking broadly, by introducing hot carbonic acid into a gas-producer fired with coal, a saving of one-half of the fixed carbon, or say one-third of the weight of fuel used, should be realised, and in addition to this saving, as the new furnace utilised the sensible heat of the gases leaving the producer (which heat was necessarily lost in the original form of Siemens furnace), and also saved considerably in the deposits of soot and tar in the flues, a further saving of one-third of the weight of fuel was made as compared with the original Siemens furnace. It should therefore be possible to do in the new form of furnace a certain amount of work with about one-third of the coal that would be required in the original form of Siemens furnace. This saving was realised in practice in iron-heating furnaces, which, as shown in the tables, worked with a consumption of about 2 cwt. of coal to the ton of iron heated to a welding temperature, whereas 6 or 7 cwt. of coal per ton of iron heated was the consumption of fuel returned in the applications made in England for the same purpose under the direction of the late Sir William Siemens. He was much obliged to the members for the manner in which they had received his paper; and as he had been asked to give the results of working the new Siemens furnace two or three years hence, he should then be happy to offer another paper, giving the results of the applications of the furnace to steel-melting.

The PRESIDENT proposed that the best thanks of the Institute be given to Mr. Head for his very interesting paper.

The motion was adopted by acclamation.

The following paper was then read:—

ON THE CRITICAL POINTS OF IRON AND STEEL.

BY MONSIEUR F. OSMOND, PARIS.

If iron and steel are submitted to a gradual heating or to a slow cooling between the ordinary temperature and that of fusion, and if the variations of some physical property in relation to the temperature are followed, it will be seen that these variations, besides being subject to a constant law, present remarkable phenomena at certain critical temperatures.

In order to find in scientific literature the first reference to these anomalies, it is necessary to go back to Gilbert, who discovered in 1600 that when a magnet is heated to redness it loses all traces of magnetism. It is, however, not my intention to refer here to the history of the question. This has been admirably summarised by Professor Roberts-Austen, in a lecture delivered at the Newcastle Meeting of the British Association in 1889.* I will merely give at the end of this paper a list of original memoirs which have been published, to my knowledge, during the last twenty years, and in which English science, represented by Gore, Barrett, Tait, Tomlinson, Hopkinson, and others, has taken a considerable part.

When I commenced, in October 1886, to study the critical points of iron, a certain number of important facts were already known. But as the first experimenters did not possess the means of accurately determining high temperatures, and as they did not, as a rule, make analyses of their samples, it was difficult to make a comparison of their results, and to decide what was the share of iron and of carbon respectively in the results observed. It was, therefore, necessary to collate the known facts rather than to discover new ones. This is what I propose to do in determining as accurately as possible the position of the critical points, their causes, and their relations to each other.

* *Nature*, November 7 and 14, 1889.

EXPERIMENTAL METHOD.

It was known at the commencement of the research that the phenomena to be studied were the results of either chemical reactions or allotropic changes, or both. But as all these phenomena are indicated by a liberation or absorption of heat, I thought that the classic method of cooling would be the most suitable for my purpose.

A series of samples of suitable chemical composition were heated to a known temperature, and accurate measurements were made, during their cooling, of the time required for the temperature to be lowered an equal number of degrees. Every abnormal delay or acceleration in the fall of the thermometer should indicate a liberation or an absorption of heat, or, in other words, a critical point.

The measurement of the time presented no difficulty. This was not the case with the measurement of the temperature. I was fortunate enough, however, to be able to employ the thermoelectric pyrometer, which has recently been devised by M. H. Le Chatelier,* and which proved to be thoroughly well adapted for my researches.

Le Chatelier's couple is formed of a wire of pure fused platinum and a wire of platinum alloyed with 10 per cent. of rhodium, fastened together at one end. The opposite ends, maintained at a constant temperature, are connected by means of copper conductors to the aperiodic mirror galvanometer of Messrs. Deprez and D'Arsonval.

The apparatus is first calibrated by means of well-known melting and boiling points. The melting-point of potassium sulphate (1015°C.)† and the boiling-point of ammonium chloride (340°) are particularly well adapted for the purpose.

It may be assumed that between these two points, and for higher temperatures up to 1500° , the temperature is proportional to the electro-motive force of the couple, and to the deviation from zero of the spot of light from the mirror on the graduated

* This apparatus is made by Carpentier, 20 Rue Delambre, Paris, and is described in the *Journal de Physique*, vol. vi., January 1887, and in the *Génie Civil*, 5th March 1887.

† The temperatures throughout this paper are expressed in degrees centigrade.

scale of the galvanometer. This having been arranged, the experiment is conducted in the following manner :—

The metals to be studied have the form of round or square bars, 5 to 7 millimetres (0·2 to 0·28 inch) in diameter or side, and at one of the ends of the bar, F, a small recess is filed or ground, according to the hardness of the metal, of a shape suitable for soldering the thermo-electric couple. (Fig. 1, Plate III.)

A piece, F', of the same metal, 3 to 4 centimetres (1·18 to 1·575 inches) in length, and prepared in the same way, was brought over the couple, placed in position in such a way that the junction was squeezed between the rods F and F', or the whole was firmly bound up with iron wire. (Fig. 2.)

Fig. 3 is a diagrammatic sketch of the complete installation shown in plan. The rod F is introduced into a porcelain tube in such a way that the connection may be placed in the centre of the furnace S. The platinum and platinum-rhodium wires are isolated by clay tubes. The porcelain tube is closed at both ends with cork, and through one the rod and the wires of the couple are passed. Air is thus prevented from freely circulating in the tube, and under these conditions the oxidation is very slight, so that the same rod may be submitted without appreciable alteration to a large number of successive heatings and coolings.

The ends of the wires of the couple soldered to the copper conductors are placed in two test-tubes filled with alcohol and inserted in a water-bath, E, the temperature of which is that of the cold joint.

G represents the galvanometer with its mirror *m*; L is the lamp; R the graduated scale with its reflector M. The dotted line LM*m*, indicates the path of a ray of light sent by the lamp to M, reflected from M on to *m*, and thence on to the scale.

In order to conduct an experiment, the furnace is heated to the desired temperature. When this temperature is obtained, the gas is extinguished, the whole system is allowed to cool spontaneously, and with the aid of a chronograph the moment at which the index passes across each of the divisions of the scale is noted. The error in reading amounts at most to one-twentieth of the time that elapses between two successive pointings.

In order to represent the results graphically, I take the temperatures as abscissæ, and, as ordinates, the times included between

the passages of the index over two consecutive divisions of the scale. These divisions are shown in the plates accompanying this paper by the ordinates of the corresponding temperatures, and the point representing the time occupied between two pointings is placed in the middle of the interval. A retardation or arrestation (*relentissement*) in the fall of temperature will thus be shown by a sharp point, and a delay in the cooling by a bulge in the curve—a bulge of which the area is proportional to the quantity of heat liberated.

RESULTS OF EXPERIMENTS.

(a.) *Phenomena observed during the slow cooling of iron, steel, and white pig iron between 1100° and 600°.*

I shall first study a series of samples with an increasing proportion of carbon, the other constituents remaining, as far as possible, in low and but slightly varying proportions. The following table shows the results of analyses of the samples:—

Consecutive No.	1. Electrolytic iron.	2. Extra mild steel, basic open-hearth.	3. Mild steel, basic Bes- semer.	4. Medium steel, acid open-hearth	5. Hard steel, crucible.	6. Swedish white pig iron.
Mode of preparation . . . . .	...	Forged.	Forged.	Forged.	Forged.	Cast.
Shape of rod	Rectangular.	Circular.	Circular.	Circular.	Circular.	Square.
Length of rod	25 cm. (9·8 in.)	60 cm. (23·6 in.)	60 cm. (23·6 in.)	60 cm. (23·6 in.)	40 cm. (15·7 in.)	40 cm. (15·7 in.)
Cross sectional di- mensions	10 × 4 mm. (0·39 × 0·16 in.)	6 mm. (0·24 in.)	5 mm. (0·20 in.)	6 mm. (0·24 in.)	6 mm. (0·24 in.)	6½ × 6½ mm. (0·26 × 0·26 in.)
Carbon	0·08	0·160	0·290	0·570	1·250	4·100
Silicon . . . . .	...	0·012	0·060	0·085	0·190	0·220
Sulphur . . . . .	...	0·021	0·060	0·020	0·020	0·040
Phosphorus . . . . .	...	0·029	0·052	0·050	0·021	0·018
Manganese . . . . .	...	0·110	0·270	0·230	0·100	0·120

For convenience in describing and discussing the phenomena observed, I shall designate by the letter *a*, with Tchernoff, the critical points that are associated with the hardening of steel. But, as my experiments show that the point *a* of Tchernoff is not a single point, and that there may exist several adjacent critical points of different natures, I shall term these different points *a*₁, *a*₂, *a*₃, of which *a*₁ is applied to the perturbation produced at the lowest temperature.

As, too, the same perturbation is not distinctly developed at the same temperature when the thermometer rises as when it

falls, it will be necessary to distinguish a critical point, $a_{r,1}$ for example, observed during cooling (*refroidissement*), and the corresponding point $a_{c,1}$ observed during the heating (*chauffage*).*

A symbol such as $a_{r,1-2}$ will indicate that in the sample under consideration the two points $a_{r,1}$ and $a_{r,2}$ are combined into a single one.

A symbol such as $\frac{a_{r,1}}{m}$ will indicate that the perturbation $a_{r,1}$ is incomplete.

Besides the points a , there are in grey pig irons other critical points due to the successive solidification of different constituents. These points perhaps have their analogues, although very indistinctly marked, in steels. But even admitting that the existence of these small perturbations is certain, and although their theoretical and practical importance might be considerable, their true nature is hypothetical, and it seems to me preferable to neglect them for the present.

Lastly, as certain terms may be interpreted differently, it is advisable to accurately define the sense in which I employ them.

I apply the term *hardened steel* (*acier trempé*) to steel that has been rapidly cooled from a red heat. *Annealed steel* (*acier recuit*) is steel that has been heated to a red-heat and cooled slowly. *Tempered steel* (*acier revenu*) is steel that, after hardening, has been softened, more or less, by reheating to a temperature far short of that to which it was raised before hardening.

Having decided on the symbols to be adopted, I shall now pass to a description of the facts.

Sample No. 1, Electrolytic Iron.—Strip cut from a plate and annealed at a cherry-red heat in hydrogen before testing, in order to expel occluded hydrogen.

Contrary to expectations, this electrolytic iron was found to contain a little carbon (0.08 per cent.), the presence of which has been verified by two different methods of analysis.

Notwithstanding this, of all the metals examined this iron approaches most closely to a state of absolute purity.

During the cooling, the thermometer stops abruptly at 885° , and makes a prolonged stay $a_{r,3}$ at this temperature. It then resumes, also abruptly, its downward course.

* In this notation a indicates the critical point, r , *refroidissement*; c , *chauffage*, and the numbers the positions in the thermometric scale.

A gradual arrest in the fall of temperature, commencing at 750° , presents its first principal maximum between 737° and 730° , its second subsidiary maximum between 708° and 702° , and ends at about 690° .

Lastly, a final arrest a_{r1} is produced at about 660° ; but it is almost imperceptible, and it might be confounded with experimental errors were it not found again, considerably amplified, in steel.

Sample No. 2, Extra-Mild Steel.—The course of the cooling presents three arrests, all of which are gradual, and their phases are as follows:—

	Commence- ment.	Maximum between	Conclusion.
a_{r3}	845°	825° – 819°	800°
a_{r2}	755°	736° – 725°	710°
a_{r1}	680°	662° – 655°	645°

Sample No. 3, Mild Steel.—There are two arrests in the fall of temperature:—

	Commence- ment.	Maximum between	Conclusion.
a_{r3-2}	780°	721° – 715°	690°
a_{r1}	680°	660°	640°

Sample No. 4, Medium Steel.—There is one gradual arrest and one stay. The arrest a_{r3-2} commences at about 750° , reaches its maximum between 700° and 690° , and before being completely terminated halts at the station a_{r1} at 661° .

Sample No. 5, Hard Steel.—The slight arrest in the cooling $\frac{a_{r3}}{m}$, which is directly produced at about 860° , in the curve given as example, is exceptional for the steel examined. It is an accidental fact which it was found advisable to note. The characteristic of hard steel is a single break of long duration, a_{r3-2-1} , at 674° . The stay is accompanied by an arrest in the fall of temperature which precedes and follows it, but uniting with it (commencement at 720° , end at 645°).

Sample No. 6, White Pig Iron.—Solidification point 1085° . The critical points of steels are represented by a single stay, $\frac{a_{r3-2-1}}{m}$, which is exhibited at 695° , and which unites in a continuous manner with an arrest commencing at about 710° and ending at about 660° .

(b.) *Discussion of the Results.*

We are now enabled to discuss these results, which are all plotted in Plate I.

A glance at the superimposed curves shows that the station a_{r1} goes on increasing from the electrolytic iron, where it is almost *nil*, up to the hardest steel, where it assumes enormous importance. Thus, a is a function of the proportion of carbon, and it may at once be identified with the phenomenon to which Barrett, who discovered it in 1873, applied the name of *recalcescence*.

Nevertheless, in the examples I have given the temperature remains nearly stationary, and does not rise as it did in Professor Barrett's experiments. This difference is unimportant. For the same steel, it is possible to have indifferently recalcescence, stay, or simple retard, according to the relative velocities of the cooling and of the reaction which liberates the heat, the reaction itself being more or less rapid according to whether it was more or less retarded. These phenomena are analogous to those of surfusion.

The cause of the liberation of heat, which takes place at a_{r1} , may easily be determined. Indeed, Brinell's researches have shown that the carbon of steel is in the state of *hardening carbon* (*carbone de trempe*) above a_{r1} , and that it is in the state of *cement carbon* (*carbone de cémentation*) below that temperature. Thus, the recalcescence a_{r1} represents the change of hardening carbon into cement carbon, and this change is effected with a violent evolution of heat.

It is known, too, from the researches of Dr. Müller* in Germany, of Sir Frederick Abel and Mr. Deering† in England, and of Messrs. Osmond and Werth‡ in France, that cement carbon, termed also *carbide carbon* (*carbone de recuit*), is combined with the iron in the form of a compound probably having the definite composition Fe_3C . The true state of the hardening carbon is less accurately known, but it appears probable that it is that of free carbon simply dissolved in the iron, or perhaps that of hydrocarbon. Thus a new and more precise definition of recalcescence

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxii. p. 385; *Stahl und Eisen*, vol. viii. p. 291. See also abstract in this *Journal*, 1886, p. 365.

† *Institution of Mechanical Engineers Proceedings*, 1885, p. 30; abstract in this *Journal*, 1885, p. 222.

‡ *Annales des Mines*, 8th series, 1885, vol. viii. pp. 5-84.

may be given as follows:—*The liberation of heat which produces recalescence is the result of the chemical combination of the iron with the carbon; and conversely the absorption of heat during heating a_{c1} corresponds to the dissociation of the carbide Fe_3C , a compound which is stable at low temperatures.* It is in this way that carbonic anhydride and lime combine or separate, according as the temperature is lower or higher than the dissociation-point of calcium carbonate.

This explanation, which I believe to be in accord with that of Sir Frederick Abel, merely brings the compounds of iron and carbon within the ordinary laws of chemistry. If, as is generally admitted with Caron, hardening carbon were more intimately combined with the iron than is cement carbon, the absorption of heat would prove the existence of carbide of iron stable at high temperatures. It would then be included within the class of explosive substances, and recalescence would not be, as it is, a reversible phenomenon.

The *direct* combination of free iron with free carbon may appear somewhat paradoxical; but, in the state of hardening carbon, and at high temperatures, carbon is very different from the carbon in polymeric compounds with which we are accustomed to deal at ordinary temperatures. In this form it possesses a particular chemical activity, which enables it to combine *directly* not only with iron, but also with hydrogen and nitrogen (Forquignon's experiments *).

It should be noted that the station a_{r1} , which increases from the extra-mild steel up to the hardest steel, diminishes, on the other hand, on passing from hard steel to white pig iron. It follows, therefore, that in the latter the greatest portion of the carbon remains in the same state before and after recalescence. Is it hardening carbon that exists in the cooled pig iron, or does the cement carbon remain combined at a red heat? The latter alternative is the true one. This is proved by the experiments of my friend M. Werth, who has found that the residue, isolated by Weyl's method from the identical white pig iron employed in my researches, contained but a minute proportion of iron—that is to say, of iron carbide. Besides this, a portion of the hardening carbon easily assumes the form of graphite in very

* *Annales de Chimie et de Physique*, 5th series, vol. xxiii.

pure and highly-carburised pig irons. To effect this, it is merely necessary to heat the white pig iron slightly above its melting-point, and to allow it to cool slowly.

Even in steel, carbon never assumes one of its two forms, hardening carbon or carbide carbon, to the complete exclusion of the other. This may depend on the fact that the rate of cooling is never infinitely great nor infinitely slow, and also on the nature of the medium in which the reactions are effected. In fact, it is assumed that in a solid, where the molecular movements are very limited, all the atoms of carbon are not able to reach the atoms of iron necessary to combine with them.

The temperature at which this combination is effected tends to slowly rise, under the conditions employed in my experiments, in proportion to the increase in the amount of carbon contained in the metal.

The position of the maximum of a_{r1} is as follows:—

1. Electrolytic iron	660°
2. Extra-mild steel	662°-655°
3. Mild steel	660°*
4. Medium steel	661°*
5. Hard steel	674°
6. White pig iron	695°

It is, however, probable that the temperature of combination is theoretically constant; but the reaction is retarded in practice by the comparative scarcity of the carbon.

Let us now examine the critical points of iron.

In electrolytic iron during cooling, two abnormal evolutions of heat occur. One, a_{r3} , commences and ends abruptly, and causes at 855° a fairly prolonged stay of the thermometer; the other a_{r2} , is less distinct, and has no precise limits. It extends from about 750° to 690°, passing through two unequal maxima.

The same critical points are found in extra-mild steel; a_{r2} preserves its position and character, but the station a_{r3} is converted into a gradual slackening between about 845° and 800°, with a maximum at about 820°.

In mild steel a_{r3} is still lower, and becomes confounded with a_{r2} into a single gradual slackening, a_{r3-2} . It is easy to show, by measuring the areas of the bulges in the curves, that the quantity of heat liberated at a_{r3-2} by mild steel is practically equal to the

* The two samples 3 and 4 containing a little more manganese than the rest, the point a_1 is comparatively a little lower, as will subsequently be seen.

sum of the quantities of heat $a_{r_3} + a_{r_2}$ liberated at two points by the preceding sample.

In medium steel, the double point $a_{r_{3-2}}$ continues to descend. Its maximum, between 700° and 690° , is still distinctly separated from a_{r_1} , but the end of the arrestation coincides with recalescence.

Lastly, in hard steel, all the critical points are united into a single one, $a_{r_{3-2-1}}$ at 674° .

To sum up, in proportion to the increase in the amount of carbon, a_{r_3} is rapidly lowered (excepting occasionally a small residue which remains in the original position) and first joins a_{r_2} ; then the double point $a_{r_{3-2}}$ descends in its turn, and finally coincides with a_{r_1} . The superimposed curves in Plate I. clearly show this progress of the phenomena.

Since the point a_{r_3} is the more individualised the nearer the iron approaches to purity, it is evident that this point corresponds with a molecular modification of iron. *Iron is a polymorphous element*, like sulphur, silicon, &c.

In the present state of our knowledge, it is difficult to say whether a_{r_2} is a second distinct molecular modification of a_{r_3} , or whether it is simply the end of a_{r_3} retarded by the presence of a little carbon.

In support of the second opinion, which appears to me the more probable, it may be urged—

1. That the best known molecular changes are effected at a well-defined temperature, which is not the case with a_{r_2} .
2. That as the presence of a sufficient quantity of carbon causes a_{r_3} to descend as a whole, it is natural that a slighter quantity of carbon partially produces the same effect.
3. That carbon is not uniformly distributed throughout the mass of the metal, and that a very mild steel may be considered as a mixture of pure iron and harder steel.
4. That the curve of the thermo-electric powers of iron, compared with that of carbon, does not exhibit any distinctly marked point at a_2 .*

None of these arguments, however, is decisive, and it is merely *probable* that a_{r_2} is the retarded end of a_{r_3} . I therefore accept this view provisionally and until it is disproved, and shall assert that iron below a_{r_2} possesses the molecular form α , and assumes above

* *Transformations du Fer et du Carbone.* By F. Osmond.

a_{r3} the allotropic form β . Between a_{r2} and a_{r3} , when these two points are distinct, the metal is a mixture of the two varieties α and β .

The action of carbon on iron in steels and white pig irons may now be summarised in a few words.

Carbon, in the state of hardening carbon, maintains iron in the β condition, during slow cooling, up to a temperature which is in inverse proportion to the amount of carbon contained in the metal.

It is evident that the sudden variations observed by different investigators in the physical properties of iron and steel, may be referred to one of the points a_1 , a_2 , or a_3 .

The following are a few selected examples:—

1. Gore's phenomenon and Barrett's recalcence are at once identified with a_{r1} , or more generally with the triple point a_{r3-2-1} .

2. Pionchon, in his researches on specific heat, found the two points a_{r2} and a_{r3} in commercial iron and in iron reduced by hydrogen; but he placed his point a_3 between 1000° and 1050° , that is to say, at a temperature a little too high.

3. Hopkinson's experiments on the magnetic properties of iron and steel identify, in a highly satisfactory manner, the appearance and disappearance of magnetism with the point a_3 if it is isolated, and with the multiple point containing a_3 if the latter is not independent.

4. Le Chatelier has shown the coincidence of a_3 with the abrupt variation occurring in the law of the dilatations of soft iron.

5. The same observer found two remarkable points in the curves expressing the electrical resistance of steels as a function of the temperature. One of these points corresponds to a_3 , and the second appears to refer to a_1 .

6. I myself have found, on repeating Tait's experiments on my samples, that the thermo-electric power of iron passes through a singular point at a_3 for soft iron, and at a_{3-2-1} for hard steel.

It is thus evident that the greater number of the experiments made before or after mine are in accord with them. If, among the observations published, there are any others that appear to be discordant, it may be hoped that all difficulties will soon disappear, either when the numerous causes capable of displacing

the critical points are better known, or when the temperatures have been determined by processes that admit of comparison.

(c.) *Influence of the Initial Temperature and of the Rate of Cooling on the Position of the Critical Points. Theory of Hardening.*

If the same samples are submitted to a series of successive heatings and coolings in which the maximum temperature of heating is gradually increased, it is found that the recalescence is lowered, fairly rapidly at first, then very slowly when the cooling starts from a higher initial temperature.

The position of recalescence is similarly lowered when the cooling is accelerated, as is shown by the following figures:—

Cooling.	Medium Steel.			Hard Steel.		
	Duration of Cooling between 685° and 658°	Recalescence a_{r1} .		Duration of Cooling between 705° and 678°	Recalescence a_{r2} .	
		The Thermometer Stops at	The Thermometer Rises at		The Thermometer Stops at	The Thermometer Rises at
Slow in tube	Seconds. 116.0	653°	656°	Seconds. 49	671°	675°
Ordinary in tube	24.5	648°	655°	20	670°	680°
Rapid in air	not determined	637°	640°	not determined	642°	651°
Very rapid in water	„	absent	absent	„	absent	absent

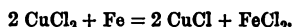
During the hardening in water, an arrest in the fall of temperature is no longer noticed.

Thus, when the rate of cooling is fairly considerable, the changes produced during slow cooling are not produced, at least integrally. Hardened steel is a steel in which the iron and carbon have preserved more or less completely in the cold the condition which they possessed at high temperatures. The heat of the change that has not been effected remains disposable in the metal, and may be termed the latent heat of hardening.

As it is difficult to observe, during cooling in water, an even comparatively lengthy arrestation of the thermometer, the preceding conclusions might appear very slight. They are, however, confirmed by two other methods.

1. I dissolved in equal volumes (500 cubic centimetres) of a 1890.—i.

saturated solution of the double chloride of copper and ammonium, equal weights (1.5 gramme) of different steels, successively annealed and hardened, and I measured the quantity of heat liberated in each case by the reaction.



The rises in temperature, after all corrections were made, were found to be as follows :—

	Annealed.	Hardened.
Medium steel	2°366°	2°477°
Hard steel	2°148°	2°309°
White pig iron	1°665°	1°878°

In other words, the hardened metal invariably contains an excess of heat in comparison with the same metal annealed.

2. I have traced the heating of hardened steels, and I have shown that the liberation of the latent heat of hardening is rendered evident by certain characteristic accelerations in the progress of the heating. I shall, however, return to these experiments subsequently.

Thus the existence of the latent heat of hardening is abundantly demonstrated. Moreover, the delay in chemical reactions and in molecular changes is a general and well-known fact. All these phenomena necessitate a certain time, and, as a rule, are possible only within a certain interval of temperature. They become incomplete if the circumstances under which they may be effected are not maintained for a sufficient length of time. In this way Sainte-Claire Deville, by very rapidly cooling the products of the dissociation of water, kept the oxygen and hydrogen separate up to the ordinary temperature, whereas with a less abrupt cooling they recombined. In this way sulphur cooled from a suitable temperature assumes the condition of plastic sulphur, and preserves, for some time at least, this particular form, which is the form of stable equilibrium above 260°.

It now remains to determine the share of iron and that of carbon in the new properties communicated to steel by hardening.

In opposition to the opinion generally accepted, I believe that it is not carbon, but the allotropic β -iron, which is the principal cause of these new properties.

This theory would be placed beyond doubt if it were proved that (1) a steel containing much hardening carbon could be soft; and that (2) a steel containing very little hardening carbon could be hard.

In order to establish the first proposition, I hardened my medium steel (sample No. 4) between $a_{r_{3-2}}$ and a_{r_1} , that is to say, when the change of the iron is already well advanced, although that of the carbon has not yet commenced. Under these conditions the metal was soft under the file, and when treated with nitric acid gave the reaction for hardening carbon. This experiment, however, has been criticised, not without reason, by Mr. Howe. It is indeed possible that the steel thus hardened, although less hard than the file, had acquired a certain amount of hardness; and, on the other hand, the nitric acid reaction, as applied, is simply qualitative.

I admit, therefore, that this test is not conclusive, although it appears to me to agree with those of M. Nouel, engineer of the Cie. de Chatillon et Commentry, in his researches on dilatation.

The second proposition, however, lends itself to a more satisfactory demonstration, and it is easy to prove by figures that very mild steel may be considerably hardened in the absence of notable proportions of hardening carbon. For this it is merely necessary to harden from a higher temperature at a_{r_3} , and to render the cooling extremely rapid by plunging a bar of slight thickness into a freezing mixture. Under these conditions the tensile strength may increase from 42 kilogrammes per square millimetre* of the original section (annealed metal) to 97 kilogrammes† (hardened metal), whilst the elongation decreases from 30 to 4 per cent. We have thus to deal with a steel containing 0.22 per cent. of carbon, only a small fraction of which has retained the form of hardening carbon.

It follows that the hardening carbon is not responsible for the enormous diminution in the malleability that has just been shown.

Moreover, electrolytic iron clearly shows that iron, in the absence of carbon, may acquire the hardness of hardened steel.

I conclude that *hardened steel owes its properties principally to the*

* 26.6 tons per square inch.

† 61.5 tons per square inch.

presence of β -iron, which is hard and brittle by itself at the ordinary temperature.

The influence of carbon is of the same character as that of the rate of cooling, and both combine to produce the final result. The rate of cooling alone is not sufficient under the ordinary conditions in which hardening is effected to maintain an appreciable fraction of the iron in the β -condition. But as, under the same conditions, it is easy to maintain the carbon in the state of hardening carbon, and as the hardening carbon imparts stability to β -iron, it is evident in what manner β -iron may be successfully preserved up to the ordinary temperature by the aid of carbon.

The more rapid the cooling, the more incomplete are the changes and the harder is the hardened metal.

(d.) *Phenomena observed on heating the same samples between 600° and 1100°.*

I append a comparative table of the critical points in cooling and heating. I may, however, remark, that the determination of these critical points is not as sure during heating as during cooling, on account of the irregularities in the pressure of gas and of water that supplies the blast.

	a_3			a_2			a_1		
	Limit.	Maximum.	Limit.	Limit.	Maximum.	Limit.	Limit.	Maximum.	Limit.
Electrolytic iron : cooling	855°	855°	855°	750°	733°-705°	690°	Doubtful. Absent.		
„ „ heating	900°	867°	840°	730°	720°	710°			
Extra-mild steel : cooling	845°	822°	800°	755°	730°	710°	680°	658°	645°
„ „ heating	92°	900°-864°	835°	755°	725°	?	...	590°?	...
Medium steel : cooling .				750°	695°	united	661°	645°	
„ „ heating .							720°	705°	690°
Hard steel : cooling .							720°	674°	645°
„ „ heating .							720°	705°	700°

It is thus evident that all the critical points studied are rever-

sible, as might have been expected, since they are reproduced identically by a series of successive coolings of the same sample.

α_2 alone is situated in the same interval of temperatures on heating as on cooling.

For the other critical points, their temperature is higher during heating than during cooling. It is true that the temperature of steel rods when heated or cooled is never quite the same at the surface and in the interior, whence it follows that the temperatures indicated by the couple are somewhat low during the cooling, and somewhat high during the heating. But the normal error which results from this fact is very much smaller than that which is observed in the majority of cases, and which has been also noted by other authors (Norris, Brinell, Newall, &c.). It is probable, however, that the theoretical temperature of the critical points should be the same in both cases; but as the chemical reactions, as well as the dimorphous changes, acquire a certain velocity only when the system is sufficiently distant from its conditions of equilibrium, it is constantly found in practice in the presence of more or less lengthy delays due to the rate of heating and of cooling. In the special case of steels, these delays may still be exaggerated for the combination of iron with carbon, by the solid condition of the medium, and for the change of the iron by the presence of carbon. The loss between α_{r3} and α_{c3} is at a minimum for electrolytic iron.

These experiments confirm and explain an important fact observed by Brinell, namely, that the temperature to which a steel must be heated to enable it to acquire hardness, and that at which it suffices to plunge it into water for hardening it during its cooling, are not identical.

(e.) Heating and cooling below 600°. Theory of tempering.

Iron and steel previously annealed do not present critical points in this region. This is, however, not the case with hardened steel.

It is known that hardened steel, reheated at increasing temperatures, loses by degrees the hardness and brittleness imparted to it by hardening. From this it may be concluded that the latent heat of hardening is liberated during tempering, and should produce characteristic accelerations in the rate of heating.

These suppositions are completely confirmed by experiment. Plate III. shows a comparison of the curves of reheating of the same steel annealed and hardened.

The liberation of the heat of hardening begins to be exhibited at about 200° under the conditions of the test; it presents its maximum at about 350° , and appears to cease at about 520° . A final liberation of heat is exhibited between 660° and 680° , quite near to the station marked $a_{c-3-2-1}$. Hence, it follows that iron and carbon which in hardened steel were not in equilibrium, just like plastic sulphur, tend to resume, as far as circumstances will allow them, their state of equilibrium, which is normal at the temperature under consideration. Thus, *during tempering, the β -iron returns to the α -condition, and the hardening carbon to the condition of iron carbide.*

In the present state of our knowledge, however, it is not yet known whether the changes of iron and carbon are successive or simultaneous, nor is it known what certain interpretation to give to the different accelerations observed during heating. Does the iron assume the α -condition when the hardening carbon which maintains it in the β -condition has combined with the iron? Or can the β -iron, on the other hand, left to itself, subsist up to a higher temperature? This is difficult to decide, in spite of the important researches made on tempering, notably by Barus and Strouhal.*

These physicists have shown that, at the melting-point of lead, steel previously hardened recovered, almost but not completely, the electrical resistance and thermo-electric constants of annealed steel. The melting-point of lead coincides, moreover, with the maximum of acceleration observed by me during the reheating after hardening (about 350°). On the other hand, the specific magnetism of steel tempered at 330° is very different to that of the same metal annealed; and the second acceleration shown by my curve between 660° and 680° (an acceleration which is, moreover, confined to very hard steels) proves that the effects of hardening are not completely destroyed at this temperature.

The question is in reality very complicated. M. Werth and

* *Bulletin of the U.S. Geological Survey*, Nos. 14 (1885) and 35 (1886); *American Journal of Science*, vols. xxxii. (December 1886), xxxiii. (January 1887), xxxiv. (July 1887); *Washington Laboratory Bulletin*, No. 27.

myself have clearly shown, on a steel of medium hardness, that tempering in a bath of lead at about 400° brings back the carbon to the state of iron carbide as completely as annealing at redness. If, however, the chemical state was the same in the two cases, it was not so with the physiological state of the carbon. Although Weyl's method isolates the carbide from annealed steel in the form of brilliant metallic spangles, the carbide from tempered steel, with the same percentage composition, appears in the form of a dull amorphous powder. The carbide is formed *in situ*, and remains in a state of infinitely fine division. Like the hardening carbon which has produced it, it cannot, at the comparatively low temperature of 400° , be collected into scales, as it is at a red heat. Hence there is a great difference in structure, which appears to have a considerable influence on certain physical properties, and above all, on the comparative mechanical properties of annealed steel and of tempered steel.

It is a noteworthy fact that the change of the carbon is gradual. This fact is in complete accord with daily practice, which shows that the effect of tempering is proportional to the temperature attained. It is rendered evident by the shape of the curve of reheating; and Barus and Strouhal have proved that, for a given temperature, steel previously hardened tends towards a state of equilibrium which depends only on the temperature, and which is attained the more rapidly the higher this temperature is. The reaction being possible, it would appear to be complete, as any tendency to the inverse reaction does not limit it to the temperature under consideration. If this is not the case, the solid nature of the medium does not permit, at the desired moment, as a liquid or gaseous medium does, the contact of all the atoms that ought to combine. Perhaps the tardy liberation of heat between 660° and 680° should be attributed to the same cause.

It is evident that before the broad principles of the theory of tempering are developed, the details must be worked out.*

(f.) *Influence of foreign elements.*

In the first place, I must express my thanks to the metallurgists

* The more affirmative theory I formerly enunciated now appears to me after much investigation and reflection, to have been premature.

who have kindly procured samples for me, notably to Professor Roberts-Austen and to Mr. Hadfield in England, and to Messrs. Jordan, Brustlein, and Lèdeboer in France. Thanks to their help, I have been able to study, more or less completely, the influence of the following elements:—boron, nickel, manganese, copper, chromium, tungsten, silicon, arsenic, phosphorus, and sulphur.

Boron.—A single sample was examined, prepared by Professor Roberts-Austen, who obtained it by casting iron and crystallised boron together *in vacuo*.

The curves of cooling, each of which is the mean of two concordant tests, are plotted in Plate II. (The bulges in the curve are not very distinct on account of the extreme smallness of the sample, which did not weigh more than 4 grammes.)

Two liberations of heat were noted:—

$\frac{a_{r3}}{m}$ of which the maximum is produced between 815° and 805° .

$a_{r3} + \frac{(m-1)a_{r3}}{m}$ of which the maximum is produced between 735° and 725° .

The two liberations of heat are fairly equal, notwithstanding that in the iron a_{r3} is three to four times stronger than a_{r2} . It follows that the boron has lowered a_{r3} for a portion from 40° to 50° , and for the rest from 120° to 130° up to a_{r2} . This action is analogous to that of carbon. Moreover, the sample contained no carbon, or merely a negligible proportion, as the curve has no distinct point a_{r1} .

The liberation of heat observable between 980° and 940° during the progress of cooling down from 1200° represents the solidification of a small quantity of borate of iron, formed by the surface oxidation of the metal.

Nickel.—A single sample was examined, containing—

Carbon	.	.	.	.	.	.	.	0.337
Silicon	.	.	.	.	.	.	.	0.047
Sulphur	.	.	.	.	.	.	.	0.022
Phosphorus	.	.	.	.	.	.	.	0.223
Manganese	.	.	.	.	.	.	.	trace
Nickel.	.	.	.	.	.	.	.	5.970

It was obtained by melting together in a graphite crucible lined with magnesia—

Iron (rivets)	80 grammes
Spiegeleisen (20 per cent. Mn)	10 „
Nickel (in cubes)	4 „

The lid of the crucible having melted, the atmosphere of fusion was highly oxidising. All the manganese disappeared, and the metal was very red-short. The test was made with two rods, 5 by 5 by 25 millimetres, cut from the ingot.

The cooling (Plate II.) indicates a single station, a_{r3-2-1} at 650° , accompanied by a slackening commencing at 675° and ending at about 590° .

In a steel containing the same amount of carbon, the points a_{r3} and a_{r2} would be united into a single slackening a_{r3-2} altogether independent of a_{r1} . Thus, the nickel has considerably lowered the changing-point of the iron, and the change of the carbon has similarly been lowered.

The recent researches of Hopkinson in England, and of H. Le Chatelier in France, have shown that in steel containing 25 per cent. of nickel, the critical point is lowered below 0° during the cooling, whilst the inverse point during the heating remains near 600° . These facts are exceedingly curious. Nickel being a polymorphous element like iron, the study of the alloys formed by these two metals will be particularly interesting to pursue.

Manganese.—I have examined the following products:—

Consecutive No.	3.	7.	8.	9.	10	11.	12.
Nature		Basic Bessemer steel.			Ferro-manganese (St. Louis).		
Mode of preparation:		Forged.			Cast.		
Form of rod		Circular.			Square.		
Length of rod		60 centimetres.			40 centimetres.		
Cross section		5 mm. diameter.			7 by 7 mm.		
Carbon	0·20	0·32	0·42	0·46	...	...	...
Silicon	0·06	0·05	0·035	0·07	0·80	0·43	0·71
Sulphur	0·06	0·02	0·03	0·035	...	...	...
Phosphorus	0·052	0·051	0·093	0·073	0·098	0·11	0·065
Manganese	0·27	0·50	1·00	1·08	18·00	49·00	81·00

Sample No. 3 is the same as that already utilised in the carbon series.

Each sample of steel was submitted to two successive coolings from 1100° . The samples of ferro-manganese were not cooled from a higher temperature than 900° . They present, it is true, between that temperature and their melting-point a certain

number of special perturbations which are connected with the liquation of different constituents, and which do not bear upon the facts studied in this paper.

The results obtained are given in the following table:—

	Per-centage of Mn.	a_{r3-2}			a_{r1}		
		Com-mences about	Maximum between	Ends about	Com-mences about	Maximum.	Ends about
Steel, No. 3, 1st cooling	0.27	780°	720° - 715°	690°	680°	660°	640°
„ No. 7, 1st and 2nd cooling . . .	0.50	740°	705° - 697°	660°	660°	640°	620°
„ No. 8, 1st and 2nd cooling . . .	1.00	725°	655°?	combined		625°	600°
„ No. 9, 2nd cooling	1.08	725°?	658°?	combined		620°	595°
Ferro-manganese . . .	18.00	...		no arrestation noticeable.			
„ . . .	49.00	...		„	„		
„ . . .	81.00	...		„	„		

In proportion to the increase in the percentage of manganese, the temperature of recalescence is lowered, and that of the allotropic change of the iron is affected in the same way. Ferro-manganese exhibits nothing more than doubtful traces of arrestation. Thus, the more manganese in the metal, the longer is the iron maintained in the β -condition, and the carbon in the condition of hardening carbon. This effect is very similar to that produced by a more rapid cooling on a non-manganiferous steel containing the same proportion of carbon. In fact, the presence of manganese is equivalent to a more or less complete hardening, and this conclusion is in accord with the known properties of manganese steel. It is known that manganese lessens the malleability, increases the tensile strength, the tendency towards oxidation, the electrical resistance, and the ratio of the residual magnetism to the total magnetism. These properties, however, are due to β -iron, the proportion of which in the cooled steel increases with the percentage of manganese, and not to the manganese itself.

Hadfield's highly manganiferous steels, according to the researches of Barrett and Hopkinson, behave like ferro-manganese—that is to say, they do not exhibit recalescence. In these metals all the iron is in the β -condition, which is the normal and stable

form of iron above 860° . But β -iron above 860° is not magnetic, and this should be the case with Hadfield's manganese steels and with ferro-manganese. This being actually the case, there is a very striking experimental confirmation of the theory.

Copper.—Professor Roberts-Austen has obtained for me three samples prepared by Dr. Edwin J. Ball and Mr. Arthur Wingham—samples which have been described in a paper read before this Institute.*

Consecutive No.	23. (1.)	24. (5)	25. (6.)
Ball and Wingham's mark	Cast.	Cast.	Cast.
Mode of preparation	6 by 6 mm.	$5\frac{1}{2}$ by $5\frac{1}{2}$ mm.	7 by 7 mm.
Section of bar	27 mm.	30 mm.	26 mm.
Length of bar	10 grammes.	13 grammes.	13 grammes.
Total weight of the two bars			
Carbon, per cent.	0.102	0.183	Less than 0.1
Copper	0.847	4.100	4.44

The bars were filed from the small cast ingots, and were not regular in section throughout their length. This was, however, of no consequence. The curves are plotted in Plate II., each curve representing the mean of two tests.

The results are given in the following table:—

No.	23.	24.	25.
Copper, per cent.	0.847	4.10	4.40
a_{r3} begins about	825°
Maximum	815° – 805°
Ends about	785°
a_{r2} begins . . . . .	...	755°	765°
Maximum	710°	725° – 715°	720°
Ends	690°	660°	660°
a_{r1} begins . . . . .	...	650°	...
Maximum	660° – 650°	620° – 610°	610° – 600°
Ends . . . . .	...	590°	...

In the metal containing 0.847 per cent. of copper, the three points a_{r1} , a_{r2} , a_{r3} , are quite distinct; but a_{r3} , the normal position of which is at 855° , has already been lowered 40° to 50° . When the percentage of copper increases, a_{r3} , with the exception of a small residue remaining near the normal position, becomes confounded with a_{r2} at about 720° . Similarly a_{r1} is also lower.

* *Journal*, 1889, p. 123.

It is evident that copper acts in the same manner as the elements previously studied, but in a less energetic manner; 4 per cent. of copper having nearly the same effect on the change of the iron as 0.20 per cent. of carbon.

Chromium.—Three samples were examined. These are numbered 14, 15, and 16, and were obtained from the steelworks of J. Holtzer et Cie. at Unieux. They are in the form of forged square rods, 8 millimetres in side and 60 centimetres in length. Their approximate chemical composition, given by M. Brustlein, is as follows:—

Nos.	Carbon.	Chromium.
14	0.33	1.00
15	0.50 to 0.60	2.00
16	2.00	10.00 to 12.00

In soft chrome steel, the molecular modification of the iron α_{r3-2} begins at about 770° , exhibits its maximum at about 727° (about 720° in another test), and is not completely finished at the moment when the change of the carbon commences. The latter gives its maximum at 680° .

If these results are compared with those given by the sample No. 3 containing no chromium, but with approximately the same percentage of carbon, it is seen that the maximum of α_{r3-2} is slightly higher for chrome steel than for ordinary steel.

Samples 15 and 16, cooled from 1100° , present but one perturbation, α_{r3-2-1} , under the form of highly accentuated recalescence.

	No. 15.	No. 16.
The thermometer stops at	676°	694°
And continues its rise at	690°	716°

By another cooling of No. 16 (the hardest sample) from 800° , the recalescence is changed into a stay at the exceptionally high temperature of 744° .

On the whole, the figures given show that the presence of chromium considerably raises the temperature of α_{r1} . This influence is the opposite to that of manganese; and if manganese is equivalent to hardening, it may be said that the action of chromium on iron has some analogies to that of annealing. If chrome steels reunite in a remarkable degree certain opposite properties, and have the property of being but slightly brittle in

proportion to their hardness, we are led to believe that they owe their hardness to chromium itself, and their consistency to the comparative freedom from β -iron.

It must be noted that the influence of the initial temperature of cooling on the position of a_{r1} is greater in chrome steels than in carbon steels.

Tungsten.—Four samples, prepared by Mr. F. W. Harbord, have been procured for me by Professor Roberts-Austen. The test-pieces were cut from forged bars, the dimensions being 5 by 5 by 40 millimetres.

The chemical composition is as follows:—

Consecutive No. Harbord's mark	26. (1.)	27. (4.)	28. (7.)	29. (9.)
Carbon	0·13	0·13	0·115	0·14
Silicon	0·012	0·035	0·012	0·023
Sulphur	0·04	0·064	0·041	0·028
Phosphorus	0·097	0·071	0·09	0·041
Manganese	0·41	0·28	0·38	0·52
Tungsten	0·00	0·26	0·99	1·53

The curves are plotted in Plate III., the results being given in the following table:—

No.	Tungsten per cent.	a_{r3} .			a_{r2} .	a_{r1} .
		Com- mences.	Maximum.	End.	Maximum.	Maximum.
26	0·00	835°	805°-795°	775°	720°-710°	620°-610°
27	0·26	835°	805°-795°	775°	730°-720°	620°-610°
28	0·99	855°	805°	775°	730°-720°	610°-600°?
29	1·53	800°	775°-765°	755°	710°	540°-530°

The points a_{r3} , a_{r2} , and a_{r1} remain distinct throughout.

If tungsten steels are compared with steels not containing that element, it is seen that—

1. a_{r3} preserves its normal position and amplitude (for the fall of a_{r3} in sample 29 is sufficiently accounted for by the percentage of manganese).

2. The same remarks apply to a_{r2} .

3. When the percentage of tungsten is sufficiently high, a_{r1} is considerably lowered.

Thus, tungsten does not, up to a proportion of 1·50 per cent., have any appreciable action on the allotropic change of the iron, although it causes the change of the carbon to take place at as low a temperature as 530° , as I have had an opportunity of proving in another sample of tungsten steel which contained manganese, and was much harder than those of Mr. Harbord. Hitherto we have invariably seen the two changes of the iron and carbon displaced in the same direction under the influence of a foreign element. Tungsten has a hardening action on iron, and is analogous to that of the hardening process, not *per se*, but by the aid of the carbon which it maintains in the form of hardening carbon. These are remarkable properties, quite peculiar to tungsten. It has others; thus, in the hard steel, of which I spoke previously, the fall in a_{r1} is produced only after heating to a sufficiently high temperature. In cooling from 750° , a_{r1} appears at 670° , and is separated from a_{r3-2} ; in other words, the action of tungsten in this case becomes analogous to that of chromium, and exactly opposite to that first observed.

Silicon.—Mr. Hadfield has kindly sent me a fine series of samples selected from amongst those employed in his researches, and described in his important paper on alloys of iron and silicon read before this Institute at the meeting in September 1889.

These samples might have been prepared expressly for my researches, for the silicon in them is the only variable. Even had the variations in iron and manganese been regular and of little importance, I should also have obtained good results.

All the bars were forged, and measured 6 to 7 millimetres square and 12 centimetres long. Their chemical composition, according to Mr. Hadfield's analyses, was as follows:—

Consecutive No. Hadfield's mark	30. A.	31. B.	32. D.	33. E.	34. G.
Carbon	0·14	0·18	0·20	0·20	0·25
Silicon	0·18-0·24	0·70-0·87	2·11-2·18	2·67-2·69	4·18-4·49
Sulphur	0·08	...	0·06	...	...
Phosphorus	0·05	...	0·04	...	...
Manganese	0·14	0·21	0·25	0·25	0·36

The curves, each of which is the mean of two concordant tests

(except that for No. 30), are plotted in Plate II., and the results are given in the following table :—

No.	a_{r3} .			a_{r2} .			a_{r1} .		
	Com- mences.	Maximum.	Ends.	Com- mences.	Maximum.	Ends.	Com- mences.	Maximum.	Ends.
30	860°	830°-810°	780°	740°	725°-710°	700°	670°	660°-650	620°
31	850°	835°-825°	810°	?	720°-710°	690°	670°	660°-650	630°
32		Doubtful.		?	720°-710°	Combined.		680°-670	650°
33		Doubtful.		?	720°-710°	Combined.		690°-680	660°
34		Doubtful.		...	...	...	?	710°-700	670°

The action of silicon on each of the critical points is easily seen.

1. On a_{r3} . With increasing silicon, a_{r3} tends to rise and to approach the normal position occupied by it in pure iron (855°). At the same time the amplitude of a_{r3} rapidly diminishes. It is very much weakened even in the metal (No. 31) with 0.80 per cent. of silicon, and is reduced practically to zero in the richer samples. Moreover, it is not a case of simple displacement; a_{r3} is not found again on the curves to the right, where a_{r2} and a_{r1} preserve their normal intensity, nor to the left, where I attained with the metal No. 34 the temperature of 1400°. Silicon prevents the molecular change of the iron, and maintains the iron in the α -condition in the region where, in the absence of silicon, it invariably assumes the β -condition.

2. On a_{r2} . Silicon appears to slightly lower a_{r2} from 725°-710° to 710°-700°, but this effect is imperfectly marked. I may here repeat that a_{r2} appears to represent the end of a_{r3} ; that is to say, the allotropic change of the iron, for the molecules immediately dependent on the carbon.

3. On a_{r1} . Silicon gradually raises a_{r1} in a very appreciable manner from 660°-650° to 710°-700°, so that a_{r1} and a_{r2} are caused to coincide in sample 34. This action is analogous to that of chromium, and the opposite to that of manganese, of nickel, and of copper.

These experiments seem to show that, in the metals examined, the silicon is alloyed with the iron, and does not form with it definite compounds. Indeed, during the cooling of the sample

No. 33 from 1320°, and of No. 34 from 1400°, no abrupt and well-defined liberation of heat is observed which might correspond to the solidification of a melted portion, as is the case in pig iron.*

Arsenic.—Three samples were examined. These were prepared by Mr. F. W. Harbord and Mr. A. E. Tucker, and formed part of the series described in a paper read before this Institute.† The test-pieces were cut from forged bars, and have the dimensions of 5 by 5 by 40 millimetres. Their chemical composition is as follows:—

Consecutive No. Harbord and Tucker's mark	36. (0).	38. (4).	39. (11).
Carbon	0·12	0·12	0·14
Silicon	0·023	0·035	0·023
Sulphur	0·02	0·22	0·04
Phosphorus	0·041	0·035	0·154
Manganese	0·25	0·24	0·24
Arsenic	trace	0·51	0·55

The curves, each of which is the mean of two tests, are plotted in Plate III., and the results are given in the following table:—

No.	Arsenic, per cent.	a_{r3} .			a_{r2} .	a_{r1} .
		Begins.	Maximum.	Ends.	Maximum.	Maximum.
36	trace	835°	825°–805°	785°	735°–725°	640°–630°
38	0·51	855°	845°–835°	815°	735°–725°	640°–630°
39	0·55	885°	845°–835°	815°	730°–720°	640°–630°

Like silicon, arsenic causes a_{r3} to rise towards its normal position, and diminishes its intensity. It is probable that, with a higher percentage of arsenic, a_{r3} also disappears. The action of 0·50 per cent. of arsenic on a_{r2} and on a_{r1} is not appreciable.

Phosphorus.—Two samples were examined. Their chemical composition was as follows:—

* *Annales des Mines*, 8th Series, vol. xiv. pp. 39–59.

† *Journal*, 1888, p. 183.

Consecutive No. Nature	19. Puddled iron.	20. Basic Bessemer metal before after-blow.
Carbon	0·05	0·10
Silicon	0·08	...
Sulphur	0·02	...
Phosphorus	0·58	1·35
Manganese	trace	1·46

The curve for the puddled iron is exactly similar to that of electrolytic iron, except that a_{r3} is gradual and not abrupt. The influence of the phosphorus is not yet felt in an appreciable manner, especially as probably an important portion of the phosphorus is in the inactive form of phosphate of iron in inter-mixed slag.

On the other hand, the basic Bessemer metal previous to the after-blow gives, during the cooling from 1350° , but a single critical point, and this is very indistinct, at 680° (a_{r1}). a_{r3} and even a_{r2} have disappeared—that is to say, the iron preserves the α -condition at high temperatures. Phosphorus, therefore, acts like silicon.

Sulphur.—A red-short basic Bessemer steel, useless in practice, was examined. Its chemical composition was as follows:—

	Per cent.
Carbon	0·48
Silicon	0·08
Sulphur	0·28
Phosphorus	0·16
Manganese	0·51

The dimorphous change of the iron, a_{r3-2} , presents its maximum between 740° and 730° , and joins recalescence a_{r1} , producing a station at 671° .

On comparing these figures given by Sample No. 7, which contains the same proportion of manganese, with 0·32 per cent. of carbon, and only 0·02 per cent., we get—

	Maximum of a_{r2-3} .	a_{r1} (station).
Normal steel	705° – 697°	640°
Red-short steel	740° – 720°	671°

It is thus evident that the presence of sulphur has raised the position of the two critical points some 30° . Thus the influence
1890.—i. E

of sulphur, in so far as it may be determined from a single sample, appears to be similar to that of phosphorus and of silicon.

GENERAL CONCLUSIONS ON THE INFLUENCE OF FOREIGN ELEMENTS.

Professor Roberts-Austen, by studying the effect produced on the mechanical properties of gold by the addition of an equal weight (about 0·20 per cent.) of seventeen foreign elements, has discovered a curious relation between the results obtained and the position occupied by the added metals in the periodic classification.*

Recognising that a similar relation ought to exist in the case of iron, Professor Roberts-Austen, in his British Association Lecture at Newcastle, said: "In the case of iron, it is difficult to say what property of the metal will be most affected by the added matter. Possibly the direct connection with the periodic law will be traced by the effect of a given element in retarding or promoting the passage of ordinary iron to an allotropic state, but the future of steel will depend on the care with which we investigate the nature of the influence exerted by various elements on iron, and the thermal treatment to which it may most suitably be subjected."

Struck by the originality of these views, and by the importance they might acquire for the iron industry, I revised my early experiments with the object of explaining them, and I also undertook new ones.

All the experiments I have described in the last section of this paper, and the general conclusions resulting from them, fully confirm Roberts-Austen's law.

The names of the elements, whose action on iron is known, may be arranged as follows in two columns in the order of their atomic volumes:—

* *Philosophical Transactions of the Royal Society*, vol. clxxix. 1888, pp. 339-349.

I.		II.	
Name.	Atomic Volume.	Name.	Atomic Volume.
Carbon . . .	3.6	Chromium . . .	7.7
Boron . . .	4.1	Tungsten . . .	9.6
Nickel . . .	6.7	Silicon . . .	11.2
Manganese . . .	6.9	Arsenic . . .	13.2
Copper . . .	7.1	Phosphorus . . .	13.5
		Sulphur . . .	15.7

The elements in Column I., whose atomic volumes are less than that of iron (7.2), delay during the cooling, other things being equal, the change of β -iron (hard) into α -iron (soft), and that of hardening carbon into carbide carbon. For these two reasons they tend to increase, with equal rates of cooling, the proportion of β -iron existing in the cooled iron or steel, and, consequently, the hardness of the metal. They are, in fact, equivalent to a more or less energetic hardening.*

On the other hand, the elements in Column II., the atomic volumes of which are greater than that of iron, tend to raise, during the cooling, the change of the iron towards the normal position that it occupied in pure iron. Moreover, they render the inverse change more or less incomplete during the heating, and hasten during the cooling the combination of the carbon with the iron.† Thus they maintain the iron in the α -condition at raised temperatures and *a fortiori* in the cooled metal, and are theoretically a source of softness and malleability, like annealing. If, however, several of them increase the tensile strength and hardness of iron, it is by reason of their individual properties or of that of their compounds, but not by reason of their increasing the proportion of β -iron. In short, they directly play the part of the hardening element which was reserved to β -iron in carbon-steels.

Thus the foreign elements alloyed with iron act, first, in advancing or retarding, during the cooling, the allotropic change of

* To this list hydrogen might be added, the atomic volume of which is very low, and which renders electrolytic iron hard and brittle, as is well known. Perhaps it would be better to say, with Graham, *hydrogenium*, rather than hydrogen, for hydrogen gas does not appear to have any distinct action.

† Reservations must be made in the case of tungsten. This element exhibits, as we have seen, a certain number of anomalies, and may deviate from the law under certain conditions.

that metal, in rendering it more or less incomplete, in one direction or the other, according as their atomic volume is greater or less than that of iron.

In other words, foreign elements of low atomic volume tend to make iron assume or preserve the particular molecular form in which it has itself its lowest atomic volume, the converse being the case with elements of great atomic volume.

These conclusions are in accord with what is known of the influence of foreign elements on the magnetic properties of iron. Indeed, experiments that I have made on this subject * show that, within the limits in which carbon, silicon, sulphur, phosphorus, and manganese may vary in the manufacture of steel rails by the acid and basic Bessemer processes, these elements may be divided into two groups as regards permanent magnetism. In the first group, carbon and manganese increase the permanent magnetism; in the second, silicon, phosphorus, and sulphur have no action on permanent magnetism.

Without entering into minuter details, which belong rather to physics than to metallurgy, it is evident that we again find, as regards magnetism, a grouping of the foreign elements into two series. The elements in the first series have a lower atomic volume, and the elements in the second have a higher atomic volume than that of iron.

* *Génie Civil*, 4th July 1885.

APPENDIX.

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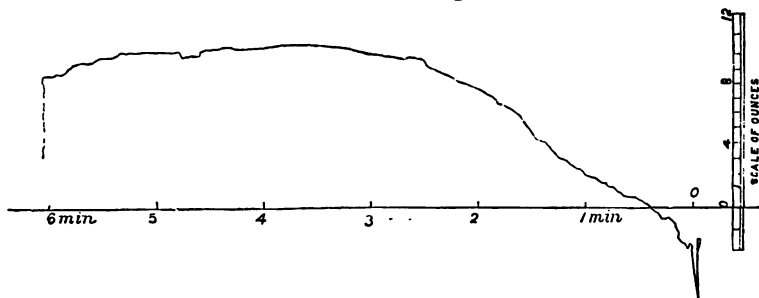
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DISCUSSION.

Mr. T. WRIGHTSON said the subject brought before the members by M. Osmond through Professor Roberts-Austen was one that interested him very much. The critical points of iron and steel having been investigated from the temperature point of view, and also from the magnetic and the electrical resistance point of view, interested him on account of the fact that some years ago, about 1879, he made a series of experiments upon the changes of volume of grey and white iron at high temperatures, and he had found that there were two critical points where iron showed sudden changes of volume which appeared to be connected with the critical points observed by M. Osmond. At the time he (Mr. Wrightson) made his experiments, he had no means of measuring the temperature at which those different changes took place, but he was glad to hear from the description of Professor Roberts-Austen that an instrument had been invented by which these high temperatures could be determined. In the experiments he (Mr. Wrightson) had made, the change of volume was determined by plunging iron balls into liquid iron. The first effect was always a sinking of the ball, but as the temperature of the ball rose it gradually displaced the liquid iron, producing a floating effect. By hanging the ball upon a delicate spring balance, and always keeping it below the surface of the metal, he was enabled to register the change of volume by reading from the contraction of the spring the increased amount of displacement that had been made in the metal. He designed and made an instrument which enabled him, with suitable clockwork, to obtain a diagram, of which the horizontal base-line represented time, and the vertical ordinates the increasing or decreasing flotation of the ball as it expanded. He made many diagrams, and they all showed a general form as under:—



When the ball was first put under the surface of the molten iron, it showed a sinking effect, which was registered by carrying the pencil attached to the end of the spring below the line of equilibrium on the diagram, which represented the density of the molten iron. As the temperature of the ball increased by being immersed in the liquid bath of iron, the pencil rose, indicating an increase in volume. The volume of the ball increased until it came to a certain temperature, when further enlargement was arrested. He was rather interested in seeing that that change corresponded somewhat nearly to one of the perturbations referred to by M. Osmond, and called by him A. r. 1. He could not exactly identify it in terms of temperature, because he had no instrument by which he could determine this, but he was satisfied that it approximated to the temperature described by M. Osmond.

He (Mr. Wrightson) had also observed a second critical point in both grey and white iron—in the latter the more noticeable. This was at the point of temperature when the iron was passing from the plastic to the liquid state, and where there was a sudden and large decrease of volume, notwithstanding the fact that the temperature was rising. His papers describing these changes of volume were read in 1879 and 1880 before the Iron and Steel Institute.*

The interesting remarks made by the late Dr. Siemens in the discussion pointed directly to the connection of the change of volume with the disappearance and evolution of heat, and with the phenomenon of recalescence. It seemed to him (Mr. Wrightson) that if they wanted thoroughly to understand the subject of the critical points of iron and steel, they ought to study as a whole not only the critical points with regard to temperature, but the critical points with regard to the volume, electrical conductivity, magnetic properties, and every other physical change. He hoped that Professor Roberts-Austen would devote his attention to this subject. He had shown great ability in investigating similar branches of metallurgy, and it was to be hoped that he would take the problem in hand, and demonstrate to the Iron and Steel Institute the laws which governed those most remarkable changes.

Professor ROBERTS-AUSTEN said that Mr. Wrightson's critical point corresponded with the transformation of combined carbon

* See the *Journal*, No. II., 1879, p. 418; and No. I., 1880, p. 11.

into dissolved carbon on heating, and conversely in cooling; there was no question about that. He also thought that the curves published by Mr. Wrightson indicated the passage of β -iron to α -iron during the cooling of the carburised mass.

Mr. R. A. HADFIELD said he greatly appreciated M. Osmond's paper, which must have required a large amount of time and labour in its preparation. It would be especially valuable to the Institute, because the field of research in question was quite an undeveloped one. He thought it should be mentioned that Professor Barrett of Dublin was really the first to clearly point out and explain the peculiar recalcence or retardations in cooling referred to in the paper. He had recently, when in Paris, through M. Osmond's courtesy, seen the apparatus employed in these experiments at the Sorbonne Laboratory, and he could confirm from actual observation the striking results mentioned.

By means of the Le Chatelier pyrometer, recalcence or retardation were easily observed, and to a practical man it was most interesting to see the molecular changes taking place in the samples under observation, especially as these changes were practically unnoticed in the ordinary treatment of iron and steel. The experiments were vividly brought before one's eyes, because by means of the spot of light from the galvanometer that formed part of the apparatus, changes of even a few degrees in temperature were readily observed.

The fact mentioned on page 59 appeared also to be very important. It was there proved that heated steel, when rapidly cooled or quenched, did not show any retardation or recalcence. This clearly brought out the great difference between quickly and slowly cooled steel, and would probably eventually help to explain the problem of the hardening of steel—a problem by no means as yet fully understood.

As a good pyrometer was of such great importance in metallurgical operations—and the speaker was glad to notice that Sir Lowthian Bell coincided with this—he thought special attention should be paid to the Le Chatelier apparatus. This apparatus was made by Mons. Carpentier, 20 Rue Delambre, Paris. The degrees of temperature in metallurgical operations were now loosely spoken of—

in fact, there was no very definite idea as to exact figures. He hoped to have a Le Chatelier apparatus in his own works very shortly, as it seemed simple and rapidly applied. A French metallurgist, M. Emilio Damour, had worked with this pyrometer and had taken the temperatures of Siemens furnaces up to about 3500° F., so that it had a very high range.

He also wished to draw attention to M. Osmond's definitions of hardened, tempered, and cooled steel. The very clear manner in which he had expressed this was, he thought, worthy of attention. If it was only adopted in metallurgical literature, much confusion would be saved. If the Institute could only see its way to draw up some definition on such lines, although, of course, it would be impossible to actually enforce it, it would nevertheless often help very much, and no doubt be eventually adopted by, all writers on such matters.

With regard to changes in the form of carbon, there were many points that were now very puzzling. He remembered, for example, some time ago discussing this question with a leading Sheffield metallurgist, who told him that the carbon in molten iron was all in the same form, or at least he so considered it; but was that really so? How could the fact be accounted for that certain kinds of grey and white iron, each respectively melted in separate crucibles, when cooled down retained their respective characters? That was to say, white iron, even if cast in sand and slowly cooled, would, at any rate in small masses, retain its white character; and *vice versa* as regards grey iron, plenty of which might be cast in chills and yet show no signs of "chilling." This seemed to show clearly that carburets or carbides of iron can retain different forms even when molten. He did not know whether this had been considered before, but it was perhaps worth attention.

He was especially glad to hear what M. Osmond had said as to the possibility of steel and iron assuming differences in molecular and chemical form. It was, of course, a difficult matter to prove that, but some years ago he had pointed out, in connection with his own researches in manganese steel, that there was an indication that the metal iron possessed several peculiar properties which were not fully understood, and that the manganese in manganese steel was not, probably, the sole cause of the peculiar

hardness in it; for instance, alloys of manganese copper were not hard, so that apparently manganese itself did not produce hardness. He merely mentioned this latter as having a bearing on this question of alloys of iron and steel. For instance, carbon could not itself give the hardness in the intensely hard and brittle 4 to 5 per cent. manganese steel, as it was there present in quantities under '30 to '40 per cent. It seemed, therefore, that there might be other forms of iron either produced by certain combinations or alloys, or which might be produced by temperature effects. M. Osmond quite appreciated the difficulty of proving that, but his remark at the foot of page 50 as to its being so, and as to there being an allotropic β -iron was well worth consideration.

Dr. Ball, in his paper on the same subject, had given some remarkable facts of water quenching mild steel, obtaining, as he (Mr. Hadfield) had done some years ago, a tensile strength of over sixty tons per square inch, of course at the expense of elongation; but still the fact remained that even carbonless iron, by certain treatment, could be made to assume a very different condition as compared with its ordinary ductile state. As regards the practical bearing of experiments in this direction, he believed that in America a method had been introduced in which the principle employed was that of noting very carefully the recalescence point, and then water-quenching the piece under treatment. Mr. Coffin of the Cambria Ironworks, Johnstown, Pa.—who unfortunately lost his life in the disaster there—took out several patents for applying this system practically. He believed that by it some specially tough and strong steel suitable for car-wheel axles had been obtained.

In conclusion, he thought that the members of the Institute were greatly indebted to M. Osmond, who had come forward in such a generous way to give the Institute the results of his valuable experiments.

The SECRETARY read the following remarks on M. Osmond's paper, contributed by Dr. G. GORE, F.R.S. :—

Having in the year 1869 been the first to observe the momentary molecular movements and magnetic changes in iron, steel, and nickel, during heating to redness and cooling, it is a great pleasure to me to know, from M. Osmond's bibliography of the subject, that

my observation of those apparently trifling facts has been followed by so many important researches made by eminent investigators. In the *Philosophical Magazine* (September 1869, p. 177), I stated, merely as an inference from my experiments, that "simply by heating a bar of iron to redness, a whole series of changes occur in its molecular structure, its magnetism, its dimensions, its cohesive power, its specific heat, its thermo-electric capacity, and its electric-conducting power." Since that time the whole of these phenomena mentioned by me have been demonstrated and my statements proved to be true by means of the skill, labour, time, and money expended upon the subject by others. The long list of researches given by M. Osmond as having been made of this molecular change in iron illustrates the great value of a mere qualitative fundamental fact, even when no accurate measurements are made respecting it by its discoverer, because it forms a basis of subsequent mathematical treatment and practical applications. The natural course, also, of scientific research in many cases is first to discover a truth, then to make accurate measurements of its conditions and relations, and, finally, to apply the knowledge thus obtained to industrial uses.

It has always appeared to me that, whilst an investigation of the influence of the chemical composition of the samples of iron, steel, and nickel, such as M. Osmond has been making, would be of great importance, and would throw much light upon the phenomenon, the phenomenon itself belongs essentially to the pure metal, and that any foreign substance present only modifies it, by increasing or decreasing its magnitude, &c. This opinion has now been largely demonstrated, especially by M. Osmond's experiments with pure electrolytic iron, and with iron alloyed with various substances.

The fact that the phenomenon occurs with the purest iron indicates that the molecular change, and its attendant phenomena, is of a much more fundamental character than if it was only a result of chemical union or separation of two different bodies, because it is an action of the molecules of a single substance, and can therefore only be explained by a mechanical and mathematical theory. And as the molecular change is attended by evolution and absorption of heat, like that which occurs when two different substances chemically combine and then separate, the same theory which

explains the molecular action will also explain ordinary chemical union and decomposition, and will thus lead towards a mechanical and mathematical basis of chemical action in general.

Further, as iron is magnetic and possesses one set of properties at one temperature, and is non-magnetic and has a more or less different set of properties at another temperature, and as difference of properties is a recognised sign of difference of substance, the molecular alteration, and the magnetic and other changes which accompany it, constitute a conspicuous example of the truth, that "every substance becomes more or less a different substance at every different temperature" (see *Philosophical Magazine*, May 1890, p. 422, "On a New Method and Department of Chemical Research").

Mr. G. J. SNELUS, F.R.S., said they were all very much indebted to M. Osmond for the very great care that he had bestowed on his experiments, and they were very much indebted to Dr. Roberts-Austen for the very lucid way in which he had endeavoured to lay these very abstruse results before the Institute. He was sure that, without the aid of Dr. Roberts-Austen, many of those present would have failed to grasp the paper as well as they had done. It was much too abstruse to carry it all away, or even to understand it at the first reading; but there was one point which had been made very clear, and that was the law that Dr. Roberts-Austen seemed to have discovered with regard to atomic-thermo influences, which seemed to be a very important one.

Sir LOWTHIAN BELL, Bart., F.R.S., said he hoped, when the discussion closed, that the President, in his own forcible language, would address to Professor Roberts-Austen and M. Osmond his warmest commendation for the information which those gentlemen had communicated to the meeting. It was of the utmost importance that they should, as far as possible, encourage gentlemen who, by education and by habit, were able to lay before them the results of pure philosophical observation. It was some years since he had ventured to refer to the changes which took place in the strength of steel rails, which he supposed might depend on the rate of cooling of the metal. He had come to that conclusion

from having observed on many occasions that when rails were broken, on being subjected to the most careful analysis, no sufficient cause had been discovered to account for the failure. The rails were delivered on the bank, and placed in piles of greater or less magnitude, which necessarily affected the process of cooling. It was not surprising that a very slight alteration in that respect might produce a considerable difference. There was one thing in connection with this question which he was extremely glad to notice, namely, that at last they had some prospect of having a pyrometer capable of giving accurate results, an instrument of great value to those who had to deal with high temperatures. Mr. Hadfield had spoken of carbon, and he had mentioned some one as having propounded the idea that when iron was in a molten state all the carbon was the same. [Mr. HADFIELD said that that was what he had been told.] That was also his own opinion, because they knew that carbon in iron could be changed from graphitic to combined with the utmost ease. He had accounted for that change by supposing that, on account of white iron being less fusible than grey iron, the solidification of the white iron was so rapid that the carbon had not time to separate from the metal in the form of kish, as happened with grey iron. It was well known that by running white iron into a large block, so that the cooling was very slow, a large portion of the carbon separated in the graphitic form. On one occasion, being anxious to ascertain the nature and the extent of the change, he had had a block of white cast iron made to fill a cube of three feet. This was split in two halves by wedges driven home by a heavy falling weight. In this way he learnt that the block consisted largely of grey iron. In like manner, when grey iron was run against a cold surface a large portion, if not the whole, of the graphitic carbon was apparently converted into combined carbon—at all events the iron so chilled, as it was termed, is white. He might be in error, but it did occur to him that in all probability, the carbon being dissolved in the iron, the difference in character was due to the circumstances connected with its cooling.

The PRESIDENT then proposed a vote of thanks to M. Osmond for

his paper, and to Professor Roberts-Austen for reading and explaining it.

The motion was agreed to by acclamation.

Professor ROBERTS-AUSTEN said that within the last fortnight he had seen his friend M. Osmond, who was extremely anxious that this complicated paper should be carefully presented to the English audience for which it was intended, and he could assure the members that M. Osmond would be much gratified at the manner in which it had been received.

The following papers were then read:—

ON THE CARBURISATION OF IRON BY THE
DIAMOND.

BY PROFESSOR W. C. ROBERTS-AUSTEN, F.R.S.

THAT the presence of carbon determines the physical properties of iron is universally recognised. It is, however, a singular fact that the mass of recent work, both theoretical and practical, which has clearly shown the importance of the presence in iron of elements other than carbon, and has enabled the nature of their action to be defined, has in no way lowered the position which carbon holds as the element which confers upon iron the wide range of properties characteristic of steel. It is also strange that, notwithstanding the wealth of literature which relates to the history of the extraction of iron from its ores, and its conversion into steel, but little has been written with reference to the historical experiments by which the true nature of steel, as distinguished from iron, was established.

I do not propose to do more than briefly allude to the writings of what may be called the critical period of the history of theoretical views concerning the constitution of steel. The period was a brief one, as it only extended over the seven years that intervened between 1774 and 1781. In 1774 Rinman showed that a drop of nitric acid simply whitens wrought iron, but leaves a black mark on steel; while in 1781 Bergman * clearly stated that steel mainly differs from iron by containing $\frac{2}{10}$ ths per cent. of carbon, while iron does not. The great professor at the University of Upsala was, as I have elsewhere shown,† not only one of the earliest workers in the field of thermo-chemistry, but a believer in the polymorphic nature of iron. The history of the metallurgy of iron at the end of the eighteenth century is, in fact, an epitome of the history of chemistry at that period. Bergman tenaciously held to the phlogistic theory in relation to steel; it was inevitable that he

* *De Analysis Terri Opuscula Physica et Chemica*, vol. iii. 1783.

† "On the Hardening and Tempering of Steel," *Nature*, Nov. 7-14, 1889.
1890.—i.

should. The true nature of oxidation had been explained by the school of Lavoisier; no wonder that the defenders of the phlogistic theory should seek to support their case by appealing to the subtle and obscure changes produced in iron by apparently slight causes. Bergman's view was, however, combated by Vaudermonde, Berthollet, and Monge,* who showed, in a report communicated to the Académie des Sciences in 1786, that the difference between the main varieties of iron is determined by variation in the amount of carbon, and, further, that steel must contain a certain quantity of carbon in order that it might possess definite qualities.

Bearing in mind the nature of Black's work, it was only natural that he, writing in 1796,† should have attributed the hardening of steel to the "extraction of latent heat;" "the abatement of the hardness by temper being due," he says, "to the restoration of a part of that heat." Osmond in the last few years has shown that such evolution and absorption of heat is the thermal evidence of molecular change in iron, which lends additional interest to the observations of Black; but, to return to the period at which he wrote, it is quite evident that the great English chemist did not see that the work of Bergman had entirely changed the situation, and even we are apt to forget how necessary it was at the time to establish the fact that carbon is really the element which gives to steel its characteristic properties.

With this object in view, Clouet in 1798 melted a little crucible of iron weighing 57·8 grammes containing a diamond weighing 0·907 gramme, and obtained a fused mass of steel. Guyton de Morveau‡ reported upon this classical experiment, which was repeated by many observers in this country, none of whose results were free from the doubt which arose from the fact that furnace gases could always obtain access to the iron, and might, as well as the diamond, have yielded carbon to the metal. The question, however, of the direct carburisation of iron by the diamond has never been really questioned since 1815, when a working cutler, Mr. Pepys,§ employed the electric current to heat iron wire and

* *Histoire de l'Académie Royal des Sciences*, 1786 (printed 1788), p. 132.

† *Lectures on the Elements of Chemistry*, vol. ii. (1803) p. 505.

‡ *Ann. de Chim.*, xxxi. (1799) p. 328.

§ *Phil. Trans. Roy. Soc.*, 1866, pp. 399-439.

diamond dust together, and obtained steel. Nevertheless, as his experiment was performed in air, the possibility of the formation of a gas containing carbon was not entirely eliminated. The question whether the presence of gas as well as of solid carbon is really necessary to effect carburisation seems to have had singular attraction for experimenters. Margueritte,* for instance, in 1865 repeated Clouet's experiment, and showed that, although carburisation can be effected by simple contact of carbon and iron in a gaseous atmosphere, it is nevertheless true that in the ordinary process of cementation the gas carbonic oxide plays an important part, which had until then been overlooked.

Graham † insisted upon this fact in his classical paper on the "Occlusion of Gases by Metals," in which he described the discovery of the occlusion of carbonic oxide by iron.

The *Journal* of this Institute for 1885 ‡ contained a reference to the interesting experiments of Hempel § who found that the diamond form of carbon unites more readily with iron than either the graphitic or the amorphous form. He employed pure colourless diamonds, which had previously been heated in an atmosphere of nitrogen, and one result of this experiment was to show that solid carbon does not carburise iron at a temperature below a red heat, provided the carbon and iron be heated in an atmosphere of nitrogen perfectly free from oxygen.

It has, however, been asserted that nitrogen is a powerful agent in the conversion of iron into steel, and for reasons which cannot be dealt with here, I am inclined to think that it is so. But the question as to carburisation was reduced by Hempel's experiments to very narrow limits, and I determined to repeat Clouet's experiments, using a vacuum instead of an atmosphere of gas. The form of the apparatus used is shown in the accompanying diagrams, which render it possible not only to use the electric current for heating pure electrolytic iron in vacuo in the presence of diamond, but to heat the iron itself in vacuo before contact with the diamond is effected, and thus to deprive the iron of its occluded gas.

* *Ann. Chim. et Phys.*, T. vi. (4), 1865.

† *Phil. Trans. Roy. Soc.*, 1866, pp. 399-439.

‡ *Journal Iron and Steel Institute*, 1885, p. 298.

§ *Ber. der deutsch-chem. Gesellschaft.*, vol. xviii. p. 998.

I am satisfied that combination of iron and diamond does not take place until a full red-heat is reached, which agrees with Hempel's statement as regards the experiments conducted in an atmosphere of nitrogen. It would, however, be well to repeat my experiment, making accurate thermal measurements by the aid of Le Chatelier's pyrometer.

It may be pointed out that these simple experiments derive their theoretical interest mainly from the assertion that no two elements can react on each other unless a third element or substance be present. It would appear, however, that a mere "trace" of such additional element is sufficient to ensure combination; for in the experiments I have described, carbon and iron, in their purest obtainable forms, were used, and the only additional matter which could have been present was the trace of occluded gas which the iron may have retained.

It is safe, therefore, to conclude that carbon can combine with iron in vacuo at a full red heat. I have thought it well to bring this fact forward at the present time, for we have seen, from M. Osmond's paper, that, after more than a century of research, carbon still retains its place as the chief element which modifies the properties of iron. The interest in its action is now more intimately connected with the molecular changes in the iron which it is capable of producing than with its own direct association with the metal.

ON THE CHANGES IN IRON PRODUCED BY THERMAL TREATMENT.

 BY E. J. BALL, PH.D., LONDON.

THE following experiments were made in the year 1884 in the Metallurgical Laboratory of the Royal School of Mines, at the request of Professor Roberts-Austen, F.R.S. They were not considered at the time to be sufficiently complete for publication, but in view of the recent work of Osmond and Le Chatelier, they have acquired a new significance, and Professor Roberts-Austen has requested me to submit them to this Institute. It will, however, be of course understood that no claim to priority is in any way suggested.

In a paper recently read before the French Academy of Sciences, M. H. Le Chatelier * has given the results of an examination of the changes in electrical resistance which both malleable iron and steel experience at high temperatures. He has observed such changes at two definite points, the one about 710°C ., and the other about 855°C . In a research on the "Electrical Resistance of Iron at High Temperature," Dr. J. Hopkinson † has observed the higher of these points though not the lower, probably because the material he used was unsuited for its determination. In a still more recent paper, Osmond ‡ gives the results of a further elaboration of his research, based on the conclusion of Roberts-Austen that it would be found that in the case of iron, as in that of gold, § the influence of impurities is directly related to their atomic volume. Osmond gives strong experimental evidence in favour of this view.

In the present paper an attempt will be made to show that changes in the magnetic capacity and tensile strength of steel,

* *Comptes Rendus*, vol. cx. p. 283; see also Roberts-Austen, *Nature*, November 7 and 14, 1889.

† *Proceedings of the Royal Society*, vol. xlv. p. 457.

‡ *Comptes Rendus*, vol. cx. p. 346.

§ *Philosophical Transactions of the Royal Society*, 1888, vol. clxxix. p. 339.

which occur at definite temperatures, may be made evident when the metal is rapidly cooled in water or in oil. The results are shown in the form of curves, and from them it will be observed that in steel quenched at certain temperatures the changes both in magnetic capacity and in tensile strength are most distinct.

The experiments consisted in heating pieces of steel to definite temperatures in a muffle, three pieces at a time. When the desired temperature was reached, one of the pieces of steel was rapidly removed from the muffle and plunged vertically into distilled water of a temperature of 15°C. , the second was similarly plunged into oil of the same temperature as the water, and the third was allowed to cool slowly in air.

The oil employed was "Ragossine," a Russian petroleum, having the specific gravity 0.90445. The temperatures were determined by placing the steel rods under examination on a thin clay slab in a muffle, and then covering them lightly with fine sand to prevent oxidation, except at one spot near the centre of each rod. At this spot there was placed a bent piece of metal-foil in direct contact with the steel, but shielded from radiated heat from the muffle walls. The fusion of this piece of metal-foil determined the temperature.

In preliminary experiments, the steel rod to be examined was placed in a porcelain tube, and this again in an iron one, the temperature being determined either by the method described above, by the Carnelly water pyrometer, or by the calorimetric method of mixtures; but it was not found possible to obtain under these conditions temperature determinations which were even approximately accurate, and it was therefore considered preferable to employ the simpler method of a pyrometric scale, which was finally adopted.

The temperatures noted were (1) the melting-point of lead, 326°C. ; (2) a dull red heat, estimated at 600° ; (3) the melting-point of aluminium, estimated at 700° ; (4) a bright red heat, estimated at 800° ; (5) the melting-point of silver, 940° ; (6) a bright yellow heat, estimated at 1100° ; and (7) a very bright yellow heat, which for tabular purposes has been estimated at 1300° .

The melting-point of aluminium is variously stated at from 600° to 800° , but it was found to melt before sodium chloride

(775°), and the mean of the several estimates was therefore taken.

Two samples of steel were submitted to examination, the one made by the basic Bessemer process, and the other by the acid open-hearth process—two widely different methods of preparation. They were in the form of rods, the Bessemer rods having an average diameter of 0.194 inch, and the open-hearth rods an average diameter of 0.212 inch. The chemical composition was as follows:—

	C.	Mn.	P.	S.	Si.
Bessemer metal . . .	0.13	0.284	trace	0.069	0.004
Open-hearth metal . . .	0.12	0.546	trace	0.089	0.011

It will be observed that whilst the percentages of carbon and of the other elements present were practically identical, that of manganese was not so concordant. It is of interest, therefore, to note that whilst the curves representing the experimental results obtained with the two steels show great similarity, the temperatures at which one of the changes takes place are higher in the case of the metal containing the larger percentage of manganese than they are in that of the steel containing less of this element.

The method of procedure consisted in cutting these steel rods into 3-inch lengths, treating them in the manner described, and after either hardening or annealing from a definite temperature, transferring them to a Hughes' magnetic balance, and noting their repellant influence on the suspended magnetic needle. This being done, a current from two pint-Daniell cells was then passed through the coil of the balance surrounding the rod under examination, and the repellant influence again observed. The rods were then placed in the multiple-lever testing-machine employed at the School of Mines, strained to the yield point, transferred to the magnetic balance, and examined as before; then replaced in the testing-machine, and the stress increased almost to the breaking point. The bar so treated was then again examined in the balance, and finally strained in the testing-machine to the breaking-point itself.

The results are shown in the curves accompanying this paper. Of these curves the lower unmarked ones in each figure represent the repellant influence of the rod on the magnetic needle of the Hughes' balance, no current being passed through the surrounding

coil. The upper curves marked *m.c.* represent the repellant influence when a current of the strength previously mentioned was passed through the balance; and the curves marked *T.S.* represent the ultimate tensile strengths. The curves shown thus — refer to the Bessemer metal, and those shown thus - - - - - to the open-hearth metal.

From the curves it will be seen that certain critical points are well marked. The first and most important of these occurs at a temperature somewhere between a dull red heat and the melting-point of aluminium (see Figs. I., II., IV., &c.); the second, though less distinctly marked, near the melting-point of silver (see Figs. I., II., VIII., &c.); and the third at a bright yellow heat (see Figs. I. *T.S.*, IV., IX., &c.).

In view of the comparative roughness of the temperature determinations, and the numerous unavoidable errors, it may fairly be considered that the first and second points correspond with the α_1 and α_2 of Osmond. The third, however, is a new point, and has not been noticed either by Osmond or Le Chatelier, whose experiments did not for the most part relate to so high a temperature. It is distinctly marked in nearly every one of the curves, the curve dropping sharply when this temperature is exceeded. (It should be observed that the next higher temperature, described as a very bright yellow, and estimated at 1300°, was about the highest attainable temperature in a muffle such as those used for nickel assay purposes, anthracite being the fuel employed.) In the tensile tests especially, this third point is most prominent, the tensile strength of the basic Bessemer rod, hardened in water, having increased from 28.9 tons as hardened from the melting-point of lead to 57.8 tons when hardened from a bright yellow heat, dropping again to 45.6 tons when hardened at a still higher temperature. Similarly, the open-hearth metal increased in strength from 25.3 tons at the melting-point of lead to 60.7 tons at a bright yellow heat, falling, however, to 48.1 tons at a further increase of temperature.

This decrease in the tensile strength, after the temperature of hardening has exceeded a bright yellow heat, is accompanied by a marked increase in the elongation.

In order to determine this third point of change with greater accuracy, another series of basic Bessemer bars was treated in the

same manner, and hardened in water as before, the temperatures being determined by the calorimetric method of mixtures. The results were as follows:—

Temperatures.		Tensile Strength.	
Melting-point of silver (940° C.)		Tons per square inch.	
1250°	. . . . .	44·08	
1293°	. . . . .	54·72	
1307°	. . . . .	60·80	
1343°	. . . . .	59·28	
1369°	. . . . .	52·44	
		52·28	

What the change is which occurs at this critical point must be the subject of further examination, but the point itself is most distinct, and the change in the nature of the metal, which reaches its maximum at this temperature, must be very considerable, as, indeed, the above experiments show.

The presence of manganese in the open-hearth steel appears to have raised the temperature at which the first change took place in the metal under examination, but it does not appear to have much affected either the second or the third critical points. In his recent paper, to which reference has already been made, M. Osmond points out that manganese has the effect of delaying the changes in iron, an effect, that is, similar to that which the experiments described in this paper would appear to indicate.

It is evident that the molecular changes which take place when iron is heated to high temperatures resemble in their nature the dissociation of chemical compounds in the sense that in both cases the process is gradual and not abrupt, beginning at one temperature and reaching a maximum at another. When this maximum temperature has been exceeded, the products of the first dissociation may again be subject to a similar change. Further, if a mixture of several chemical compounds is treated in this manner, each compound, apart from other influences, will have its own maximum temperature of dissociation, and a curve representing the general result would show a series of maxima in accordance with the number of compounds present.

So, too, with steel. If the metal is examined at any temperature between that at which the change or dissociation commences, and that at which one or other of the constituents of the metal

reaches its maximum temperature of change, the metal must of necessity be found to possess properties varying with the degree of completeness which the change or changes had attained.

In the experiments described in this paper, an effort has been made to make the gradual progress of these changes evident, by arresting and, as it were, "solidifying" them by more or less sudden cooling, at certain stages of completeness.

DISCUSSION.

Mr. G. J. SNELUS, F.R.S., said he had listened to the paper of Professor Roberts-Austen with some pleasure, but he thought it would be very interesting if that gentleman would repeat his experiment on a sufficiently large scale to enable him to analyse this compound of carbon and iron afterwards, and tell them what proportion of carbon he had got dissolved or combined with the iron. He did not see any analysis of the material; in fact, he was afraid that the diamonds had become so precious that the Professor was not able to use enough of them. It would be worth while, however, to repeat the experiment on a sufficiently large scale to make an analysis of the product. It was extremely important to know to what extent carbon could be dissolved in iron. He himself hardly looked upon it as a case of stable combination of the one element with the other; he looked upon it more as a case of solution. He thought it was more analogous to solution than to chemical combination. Of course, all solutions were to some extent chemical combinations, but in the case of carbon and iron, he thought it was a question of the solution of the carbon in the iron. As they knew, any compounds of carbon and iron which were found in commerce scarcely ever reached a total of 6 per cent. of carbon in the iron. In the case of ferro-manganese, or some combinations where manganese was present, the carbon, he believed, ran up to 6 per cent.; but in the case of ordinary alloys of iron and carbon, he himself had never found much more than 5 per cent. of carbon dissolved in the iron. Now, it was just possible that, where the diamond was used, and where they had no other element dissolved in the iron, the iron might dissolve a much larger proportion of carbon than it could do when such other elements as silicon and sulphur were present, all of which affected the solubility of the carbon in the iron. Therefore, if the experiment could be repeated on a sufficiently large scale, it would be very interesting indeed to get the analysis. Then he thought there was the converse side of this. Professor Roberts-Austen had been dissolving the diamond in the iron; he wondered whether it was possible to get the diamond out of the iron when it had

been dissolved in it. There was plenty of carbon in ordinary pig iron; they might gather hundredweights of graphite, blown about as kish, when they remelted the iron in a cupola; and they all knew that they could get large flakes of graphite between the crystals of iron, which they could remove from the iron when they had this largely graphitic iron. There was a statement in Dr. Percy's *Metallurgy of Iron and Steel* to the effect that flakes of graphite could not be detached from the crystals of grey iron, even with the point of a penknife; but he showed the Doctor twenty years ago that that was wrong, and the Doctor withdrew the statement, but it was still there in print. He showed Dr. Percy that it was not only possible to remove the graphite with the penknife, but that it could be taken off with the thumb-nail; and in his first paper, read at the Merthyr Meeting of the Institute, he showed that he could collect large quantities of this graphite, which, on analysis, turned out to be pure carbon.

Now, he said there was a large quantity of carbon dissolved in the pig iron, and the question which arose in his mind was: Is it possible, by the extremely slow cooling of this iron, with its dissolved carbon, under very special conditions, to separate the carbon—this graphite—in the form of a more solid body, a more compact body, than they had at present separated? He thought it was not at all an impossibility, and if their experimentalists would go to the extent of getting the diamonds out of the iron, that would help to get over the difficulty which Sir Henry Bessemer had first told them of—namely, that in consequence of the African people buying up all the diamonds, they prevented the workmen from carrying on their diamond-cutting trade.

He thought Dr. Ball's an extremely important paper, which would throw great light upon points that had hitherto been to a great extent got out by rule-of-thumb—he meant in the tempering of large masses of iron and steel, which were now becoming so extremely important. Every investigation which would tend to draw the lines at which these reactions took place more definitely and more decidedly had intense interest, and were of very great practical advantage.

Sir LOWTHIAN BELL, Bart., F.R.S., said Mr. Snelus had spoken

of dissolving carbon or iron, and had referred to a solution. He wished to know whether Mr. Snelus meant that it was necessary to have the iron in a fluid state before combination took place?

Mr. SNELUS—No; not absolutely in a fluid condition. He imagined that bodies might be dissolved in others that were not absolutely fluid. There was no strongly-marked line, even in fluidity.

Sir LOWTHIAN BELL said he wished to mention an experiment that he had made. He was anxious to ascertain to what extent carbon could be made to pass from cast iron into wrought iron without any approach to fusion. For that purpose he took a small plate of cast iron, and a similar one of wrought iron. He then planed the surfaces of the two plates, and had them tightly screwed together in that position so as to bring the surfaces into intimate contact, and exclude the air or any other gaseous matter. In this condition they were put into a box and covered with sand, placed in a furnace, and kept heated for a month. They were then taken out and separated, and drillings were taken for analysis. The following results were obtained:—

	Carbon.	Silicon.	Sulphur.	Phosphorus.
	Per cent.	Per cent.	Per cent.	Per cent.
<i>Cast Iron—</i>				
Before exposure.	3·248	1·870	·109	1·542
$\frac{1}{16}$ inch planed off after exposure	2·179	1·890	·104	1·539
	Decr. 1·069	Incr. ·020	Decr. ·005	Decr. ·003
<i>Wrought Iron—</i>				
Before exposure.	·044	·121	·008	·195
$\frac{1}{16}$ inch planed off after exposure	·392	·162	·009	·204
	Incr. ·348	Incr. ·041	Incr. ·001	Incr. ·009

With the exception of the carbon, the differences might be regarded as being within experimental error. On the other hand, they might, he thought, fairly infer that carbon had travelled out of the cast into the wrought iron, but the former had lost about seven times more than the latter had gained. Either, then, the impregnation of the wrought iron had penetrated to a greater depth, or there had been a gasification of carbon.

It was a great compliment to the Institute that scientific men of position, like those to whom they had listened, should make it the recipient of communications bearing upon that important branch of science, as well as of economical interest.

Mr. E. G. TOSH said, with reference to the remark made by Mr. Hadfield in the discussion upon M. Osmond's paper, as to the behaviour of white and grey iron, respectively, if remelted, and Sir Lowthian Bell's comments upon that remark, his experience as an iron-smelter was that, if white iron was remelted under the same conditions as a similar weight of grey iron—in crucibles, for instance—the white iron would remain white and the grey iron grey. But coming near to what might be called the dividing-line between the closer and more open varieties of pig iron, this fixed character was less marked. The "tins" of what was known as No. 5 in the hæmatite district being very thin, and in consequence rapidly cooled, were nearly always white, the body of the pig being grey; but similar "tins" from Bessemer iron, no matter how thin, were grey when examined under the lens.

Professor ROBERTS-AUSTEN said he thought there could be no question that Dr. Ball had isolated and, as it were, fossilised the particular points to which M. Osmond had referred, and had possibly detected the existence of a third point at a higher temperature.

With regard to the diamond in its relation to iron, older experiments had shown that it was possible to get any degree of carburisation from steel up to cast iron. His object had been merely to ascertain whether it was possible to carburise iron in the absence of any third element. He had had the opportunity of making a qualitative examination of the carburised iron produced, and, as far as he could tell, both free and combined carbon were present.

He agreed with Sir Lowthian Bell that the transfer of carbon might take place in a solid, and the experiment he described was interesting as showing that that was actually the case with regard to the transfer of carbon from one mass of iron to another. As to Mr. Snelus's question whether he could get the diamond

out, it remained to be seen whether that could be done in the laboratory; but, quoting from memory, he thought it had been done by nature.* Mr. Bauerman was present, and he could say whether or not there were recorded instances of occurrence of carbon in the diamond form in meteoric iron.

Dr. BALL said he had received a letter from the Secretary of the Institute, through M. Osmond, in which he said that he himself had observed that third point of temperature in the case of two specimens which he had examined, one of steel A of the Hadfield series, and the other an alloy, referred to in a paper placed before the Institute last year, containing 4 per cent. of copper; but he was doubtful whether the third point mentioned by him (Dr. Ball) might not be the difference after the temperature of 1260° was passed—whether the difference in the tensile strength might not be due to the fact that at a high temperature his rods were covered with a thin film of oxide, which collected a little sand, and so prevented the cooling action of the atmosphere. That might be so; to a certain extent it was, but it did not appear to him sufficiently to account for the enormous change which had taken place. Assuming that the film had not been formed, the tensile strength would have gone on increasing to the temperature at which the metal was heated and hardened, and instead of being 45° it would have been nearer 80° . Mr. Wrightson had drawn attention to experiments of his own years ago, and he had stated that at the point where the iron began to soften he had noticed an enormous change. That temperature was higher than 850° , and he was inclined to think that that was his own point. With regard to the difficulty expressed by some members of the Institute, as to the possibility of iron existing in several forms, it appeared to be forgotten that in every bar of steel there were elements present all of which, with the exception of the iron itself, were known to exist in several forms, such as carbon, silicon, phosphorus, sulphur, and even manganese; and from analogy they could almost assume as proved that iron itself was capable of existing in such forms. There was one other point which would be seen from the curves,

* The papers to which reference was contemplated were *Journal Russian Chemical Society*, vol. xx. p. 185, 1888; *Jahrbuch für Mineralogie*, 1889, p. 173.

viz., that the hardening in oil occupied an intermediate position between annealing and hardening.

Mr. R. A. HADFIELD asked what other forms of manganese existed?

Dr. E. J. BALL said that such had been asserted in chemical books, but he could not absolutely prove that it was the case.

The PRESIDENT said the members would no doubt agree with him that they had been most fortunate in having such close research and high reasoning powers brought to bear on a point of enormous and practical interest. There could be no doubt that the investigation was really the beginning of an inquiry into the laws which regulated the treatment of masses of steel. The treatment of masses of steel at high temperatures was a subject which concerned the economy of manufacture very greatly, and they were therefore deeply indebted to scientific gentlemen for bringing their power of research to bear on those matters. He would ask the members to vote the thanks of the Institute to them by acclamation.

A vote of thanks was then unanimously accorded to Professor Roberts-Austen and Dr. Ball.

DISCUSSION BY CORRESPONDENCE.

Dr. HOPKINSON, F.R.S., observes, through the Secretary, that in the remarks which he had been asked to make on the papers of M. Osmond, Professor Roberts-Austen, and Dr. Ball, he would confine himself to a statement of some very curious results which he had obtained with alloys of nickel and iron.

Several alloys had been examined, supplied to him very kindly by Mr. Riley, of the Steel Company of Scotland. The most interesting sample contained 25 per cent. of nickel. As the material was given to him, it was non-magnetisable at the ordinary temperature; that was to say, the permeability was small—about 1·4—and the induction was precisely proportional to the magnetis-

ing force. The ring on being heated remained non-magnetisable up to 700°C . or 800°C . A block of the material did not recalesce on being heated to a high temperature and allowed to cool.

On being placed in a freezing mixture the material became magnetisable at a temperature a little below freezing-point.

The material was next cooled to about 51°C ., by means of solid carbonic acid, and the curve of magnetisation was ascertained, as shown in Fig. 1, corresponding to a temperature of 13°C . From this it would be seen that the ring of the material, which was previously non-magnetisable at 13°C ., was now decidedly magnetisable at the same temperature.

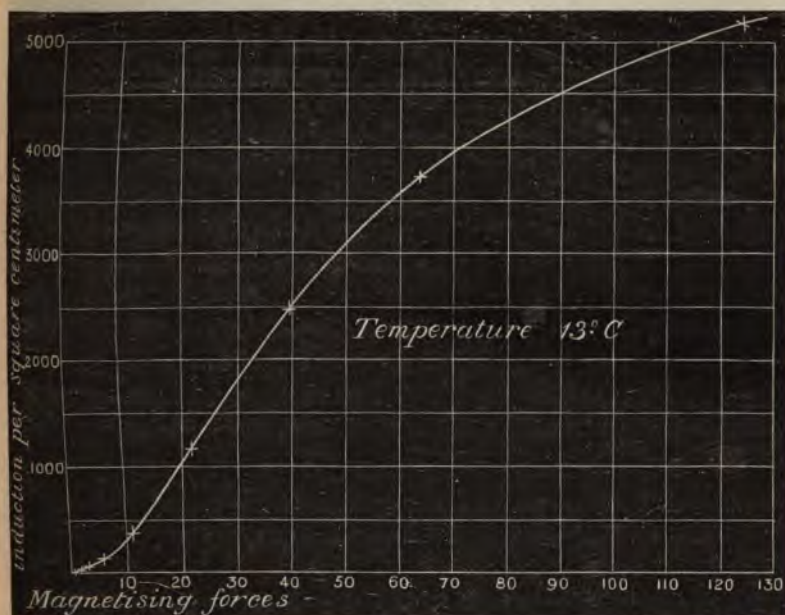


FIG. 1.

On heating the material, it remained magnetisable until it reached a temperature of 580°C . At this temperature it became non-magnetisable, and, on cooling, remained non-magnetisable to the ordinary temperature of the room. Fig. 2 showed the inductions at various temperatures, the abscissæ being temperatures for a magnetising force 6.7.

This curve showed that for a range of temperature from somewhat below freezing to 580°C . this material existed in two states, both of them quite stable—the one being non-magnetisable, the other magnetisable. It changed from non-magnetisable to

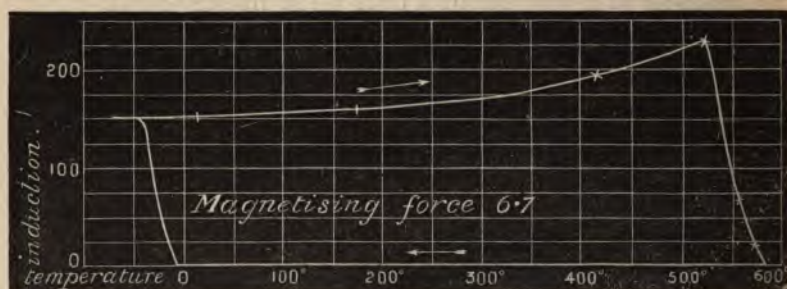


FIG. 2.

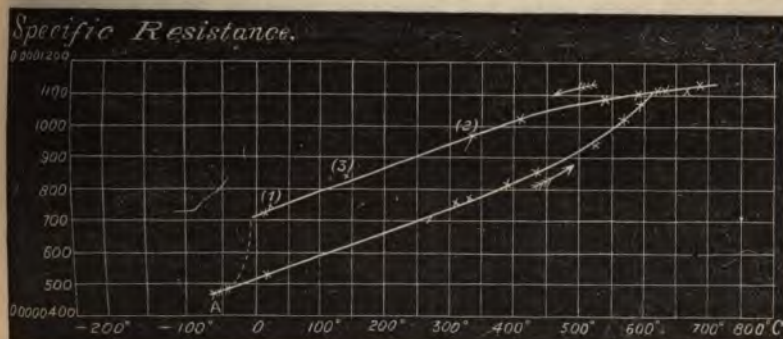
magnetisable if the temperature was reduced a little below freezing; the magnetic state of the material did not change from magnetisable to non-magnetisable until the temperature was raised to 580°C .

The same kind of thing, in a much less degree, could be seen with ordinary steel. Over a small range this could exist in two states, but in changing its state from non-magnetisable to magnetisable a considerable amount of heat was liberated, which caused a rise of temperature of the steel.

He had also tested wire of the same material. The wire as sent to him was magnetisable, as tested by means of a magnet in the ordinary way. On heating it to a dull redness, it became non-magnetisable whether it was cooled slowly or exceedingly rapidly by plunging it into water. A quantity of the wire was brought into the non-magnetisable state by heating it, and allowing it to cool. The electric resistance of a portion of this wire, about 5 metres in length, was ascertained in terms of the temperature; it was first of all tried at the ordinary temperature, and at temperatures up to 340°C . The specific resistances at these temperatures were indicated in the curve by the numbers 1, 2, 3.

The wire was then cooled by means of solid carbonic acid. The supposed course of change of resistance was indicated by the dotted line on the curve; the actual observations of resistance, however,

were indicated by the crosses in the neighbourhood of the letter A on the curve. The wire was allowed to return to the temperature of the room, and was subsequently heated, the actual observations being shown by crosses on the lower branch of the curve; the heating was continued to a temperature of 680°C ., and the metal was then allowed to cool, the actual observations being still



shown by crosses. From this curve it would be seen that in the two states of the metal, magnetisable and non-magnetisable, the resistances at ordinary temperatures were quite different. The specific resistance in the magnetisable condition was 0.000052; in the non-magnetisable condition it was about 0.000072. The curve of resistance in terms of the temperature of the material in the magnetisable condition had a close resemblance to that of soft iron, excepting that the coefficient of variation was much smaller, as, indeed, one would expect it to be in the case of an alloy; at 20°C . the coefficient was about 0.00132, just below 600°C . it was about 0.0040, and above 600°C . it had fallen to a value less than that which it had at 20°C . The change in electrical resistance effected by cooling was almost as remarkable as the change in the magnetic properties.

Samples of the wire were next tested in Professor Kennedy's laboratory for mechanical strength. Five samples of the wire were taken, which had been heated and were in the non-magnetisable state, and five which had been cooled and were in the magnetisable state. There was a marked difference in the hardness of these two samples; the non-magnetisable was extremely soft, and the

magnetisable, tolerably hard. Of the five non-magnetisable samples, the highest breaking stress was 50·52 tons per square inch, the lowest 48·75; the greatest extension was 33·3 per cent., the lowest 30 per cent. Of the magnetisable samples, the highest breaking stress was 88·12 tons per square inch, the lowest was 85·76; the highest extension was 8·33, the lowest 6·70. The broken fragments of the wire which had been magnetisable, and also of that which had been non-magnetisable, were now found to be magnetisable. If this material could be produced at a lower cost, these facts would have a very important bearing. As a mild steel, the non-magnetisable was very fine, having so high a breaking stress for so great an elongation at rupture. Suppose it were used for any purpose for which a mild steel was suitable on account of this considerable elongation at rupture, if exposed to a sharp frost its properties would be completely changed; it would become essentially a hard steel, and it would remain a hard steel until it had actually been heated to a temperature of about 600° C.

A number of other samples of different composition had also been tried. A sample with 5 per cent. nickel likewise showed two temperatures of change—one from the magnetisable to the non-magnetisable state; the other and lower temperature from the non-magnetisable to the magnetisable; the difference between them was about 200° C. With this material he had also made observations of recalescence, and found that heat was liberated and absorbed at precisely the temperature at which the magnetic changes occurred.

When, however, they tried a sample with 30 per cent. nickel, the results were quite changed. The change in magnetic condition occurred at practically the same temperatures, whether the material was being heated or cooled, this temperature being only about 100° C.

Mr. ARTHUR WINGHAM was inclined to agree with all the conclusions of the author. In respect to the question of allotropy, the behaviour of iron was quite consistent with that of other elements well recognised as assuming allotropic forms, such as sulphur, phosphorus, &c. In fact, the latter element was peculiarly comparable. It was well known that the yellow variety, on being

heated to a certain temperature, changed into the red form, which, on being further heated, underwent another change and assumed a form having the properties of the yellow variety. It seemed to be the same with iron; at a certain elevated temperature it unquestionably underwent a great change, and assumed a modification having special properties, amongst others an increased tensile strength. Now, it appeared, from Dr. Ball's paper, that steel, hardened from above a certain temperature, which he called 1100° C., commenced to lose strength again. This would seem to indicate that the iron at very high temperatures, but below melting, changed again into a form having properties which might be similar to those of the original modification. Zinc, in its changes under the influence of heat from brittleness to ductility, and again to brittleness, was an instance which showed that such changes were possible.

There was one point in the paper, however, which seemed to savour of inconsistency. M. Osmond concluded "that hardened steel owed its properties principally to the presence of β -iron;" and farther on he stated that β -iron above 860° was not magnetic, and also that manganese steels, from the fact that they did not exhibit recalescence, and that, therefore, the iron in them was in the β -condition, should be, and had been shown to be, non-magnetic. How was the permanent magnetism of hard steel to be reconciled with those facts? Apparently, hardened steel must contain some α -iron.

As regards the atomic volume, there appeared, from a cursory glance at the curves, to be another analogy existing between the arrestation and the atomic volume of the metal present. M. Osmond would no doubt be prepared to admit that the elements present in the iron not only altered the temperature at which the change in the iron took place, but that they might also be otherwise connected with that change, and that the arrestation in the fall of temperature might partly be due to the presence of the impurity itself. At any rate, it seemed curious that, with the exception of boron, the period of one of the arrestations should be great when the iron contained a low atomic volume element, and that it should decrease in the same order as the atomic volumes rose. Thus, carbon showed an arrestation of 76 seconds;

nickel, 25; copper, 17; tungsten, 11; and arsenic, 8 seconds. It was a pity, in view of this, that the percentages of impurity were so variable. Roberts-Austen's law was the most important development of the periodic law, from a practical point of view, that we have yet had.

M. F. OSMOND remarks that Dr. Ball, in his paper on the changes in iron produced by thermal treatment, had announced the probable existence of a new critical point of iron at about 1300°. Certain observations that M. Osmond had made in following the cooling of two of his samples appeared to bear upon this conclusion. The samples in question were those numbered 25 and 30 in the paper he had communicated to the meeting of the Institute.* The first was an alloy of iron with 4.44 per cent. of copper, prepared by Dr. Ball himself. The second was the first of Mr. Hadfield's series of silicon steels. The chemical composition of the two samples was as follows:—

	25.	30.
Carbon	less than 0.10	0.14
Silicon . . . . .	...	0.18 to 0.24
Sulphur . . . . .	...	0.08
Phosphorus . . . . .	...	0.05
Manganese . . . . .	...	0.05
Copper	4.44	0.14

It would be seen that the sample No. 30 resembled that studied by Dr. Ball, and this facilitated the comparison. The sample No. 30, heated to 1350°, and allowed to cool from that temperature, exhibited a distinct liberation of heat between 1300° and 1290°. The sample No. 25, heated to 1320°, and allowed to cool from that temperature, also exhibited a distinct liberation of heat between 1290° and 1280°. The same sample brought immediately afterwards to 1415°, and cooled from that temperature, no longer exhibited any liberation of heat exceeding the limit of experimental errors. These were the results of concordant experiments, and had been plotted in curves. He did not, however, discuss these results in his paper, because he attributed the liberations of heat observed to the solidification of the melted oxide; that was to say, to an external cause. This opinion was based on the following observations:—

* See *ante*, pp. 24 and 27.

1. In the experiments considered, the metals were heated in an atmosphere of an exceptionally oxidising nature, in consequence of the accidental fracture of the porcelain tube containing the metal under examination.

2. He had shown that, after the final cooling, an abnormal quantity of molten slag was formed, in sufficient proportion to determine at the moment of solidification the liberations of heat observed.

3. He had never met with the same liberations of heat when the tube remained intact during the test.

4. He had, however, met with them in other samples when heated in a highly oxidising atmosphere (an iron-boron alloy prepared by Professor Roberts-Austen, and basic Bessemer steel before the afterblow). But the presence of boric acid or of phosphoric acid had, in these cases, lowered the temperature of solidification of the slag to about 950° .

5. The liberation of heat observed during the cooling from 1320° of the cupriferous sample No. 25 was not reproduced when the same sample was cooled from 1415° . This difference was easily explained if it was remembered that the oxide formed was still pasty and adheres to the metal at 1320° , whilst it becomes very liquid and runs down into the tube at 1415° !

Although these conclusions appeared to M. Osmond to admit of no doubt, Dr. Ball's experiments induced him to verify them, and it was, indeed, very remarkable that he observed a liberation of heat at about 1300° , exactly at the temperature that Dr. Ball assigned to his new point. His first interpretation was, perhaps, not correct. He therefore recommenced his experiments on the same samples, and under the same conditions, as in the first case, merely replacing the oxidising atmosphere by an atmosphere of pure hydrogen. The results were plotted in curves, and no liberation of heat exceeding the limit of experimental error could be detected. It was therefore probable that his explanation was correct. He might incidentally mention that he had made a comparative test with electrolytic iron cooled in hydrogen and in air, and had not observed any liberation of heat at 1300° in either case. The skin of oxide formed in the air was very thin, and did not appear to be melted. It was natural that the melting-point

of ferric oxide should be higher than that of the same oxide when it was mixed with impurities, such as a little silica, copper oxide, &c.

It now remained to determine whether the fusion of the superficial slag formed in an oxidising atmosphere could account for the observations of Dr. Ball, or whether it was merely an accidental coincidence of different phenomena produced at about the same temperature.

Dr. Ball had covered his specimens with fine sand, so as to preserve them from oxidation during heating in a highly oxidising atmosphere. It was clear that, under these conditions, the oxidation was not completely effected. During the fusion of the superficial slag, the slight covering of adherent slag increased rapidly, and rendered the cooling higher during the final hardening. It was, therefore, natural that the resistance to rupture decreased from the melting-point of the slag, and above that point. He noted with pleasure that Dr. Ball attributed a certain degree of importance to this explanation, but he regarded it as incomplete, in that it did not take into account the changes observed in the resistance of the bars slowly cooled down from increasing temperatures. Dr. Ball was quite right. A very important new factor must be taken into account, namely, the changes in the structure of iron and steel with the temperature. These changes had been roughly known for a long time, but they had been studied in a more precise manner by Brinell (*Jernkontorets Annaler*, 1885, p. 5). His attention had also been directed to them in the fourth part of his *Études Métallurgiques* (*Annales des Mines*, 1888). The modification that changes in the structure effected in the mechanical properties had, however, not been studied, either by Brinell or by himself. Dr. Ball had, therefore, done well in directing his researches to this point. To sum up, there were two causes—first, the formation and scorification of the oxide, and, second, the crystallisation of the iron—which certainly affected the results of Dr. Ball's observations. Should a third cause be added to these two, and a new allotropic change of iron at 1300° be admitted? He had not sufficient proofs to absolutely deny this. He would, therefore, merely remark that neither his curves of cooling nor his curves of thermo-electric power had



indicated a change of this kind up to the present. The explanations that he offered did not detract from the interest of Dr. Ball's paper, which appeared to him to be of very great theoretical and practical importance, notably in reference to welding. Some developments of this question might perhaps be alluded to. In a letter he had kindly written to him, Dr. Ball referred his critical point to that termed by Mr. Wrightson the welding temperature of iron. This appeared to him to be correct, and to be in accord with his explanations. What was the cause that prevented iron from welding when it had been heated in an oxidising atmosphere? It was evidently the oxide formed on the surface of the bars, since iron welded at 700° in hydrogen. But this obstacle to welding ceased to exist when the oxide was melted, for the liquid oxide could run off the metallic surfaces, and it was with a view to lower the melting-point that sand and borax were employed every day in ironworks. Was it not quite natural, then, that Dr. Ball's point, identified with the welding temperature, accurately coincided with the melting-point of oxide of iron?

ABSTRACT OF PAPER ON THE ROBERT-BESSEMER
STEEL PROCESS.*

BY MR. F. LYNWOOD GARRISON, PHILADELPHIA.

THIS modification of the Bessemer process was originated in 1884, at Stenay, as the Walrand-Delattre converter. It is elliptical in shape, having a flat surface in which the tuyeres are always placed on the same plane parallel to the axis. It swings on trunnions, and the tuyeres are so arranged as to impart a rotary motion to the bath, which brings all parts of the metal bath successively under the oxidising influence of the blast. The oblique introduction of the blast causes an intimate mixture of the gases. Combustion takes place at the very surface of the bath, causing at that point a maximum temperature.

It is of advantage to be able to control the pressure of the blast, so as to regulate it at different periods of the operation. The pressure required is much less than in the ordinary Bessemer converter. The average pressure of blast is about 4 lbs., being just sufficient to keep the slag out of the metal, and produce rotation of the bath, upon the surface of which the blast only impinges.

The blow has three distinct periods—the first lasting from seven to eight minutes, the second from three to four. At the end of the second period the flame disappears, but the blow is continued for one and a half to two minutes more, in which the flame reappears, after which the converter is turned down, and about 1 per cent. of 70 per cent. ferro is added. If a basic lining is used rather more ferro is required. Acid linings must be highly refractory, owing to the high temperature employed.

The author describes the use of both acid and basic linings, and the shape, dimensions, and disposition of the tuyeres, which are slightly conical in a longitudinal direction, a shape that

* The full paper was read at the Paris Meeting of the Institute in September 1889, but the discussion was adjourned.

enables them to be withdrawn and replaced more easily. In experiments made at Paris, the carbon was reduced from 3·50 per cent. to from 0·07 to 0·30 per cent.; the silicon, which was present in the pig to the extent of 2·0 per cent., ranged from 1·60 to 3·90 per cent., and the manganese was the same in both. High-silicon pig gives a high temperature, but increases waste. With low-silicon pig, the period of decarburation is prolonged by uncovering the tuyeres, or rather decreasing the height of the metal over the tuyeres. The pig should be very hot when run into the converter.

The author describes how the basic lining is made, gives analyses of the pig most suitable for basic working, and describes the basic slag. Tables are appended to the paper showing the tensile strength of basic steel made by the Robert process, as ascertained by tests made at Blaenavon.

A statement of the results of experiments made with steel castings produced at Stenay from acid steel is also given. The consumption of materials and the production of steel, as ascertained at Stenay in May and June 1889, are set out in detail.

After pointing out that Sir Henry Bessemer, in some of his earlier experiments, provided for blowing air on or near the surface of the metal bath in a converter, the author declares that he has seen the Robert process produce some excellent material.

DISCUSSION.

Sir HENRY BESSEMER said that one was always deeply interested in looking into the various modifications of any particular apparatus originating with different minds applied to the same subject; and it not infrequently happened that very small differences effected important results. He had been looking into the subject of the paper, and was somewhat disappointed to find that the differences which one would expect to produce new results did not seem to reside there, because he found that in many of his early experiments, and in the working of others, very much the same thing had been done. For instance, the rotation of the metal in the vessel had been practised for many years in Sweden. All the early Swedish converters were fixed vessels, with the metal rising only two or three inches above the level of the tuyeres, which were all horizontal, and could be blown by the ordinary blast engine, which blew their little charcoal furnaces. Probably that was the reason why those shallow tuyeres were used. It was found, however, in working these shallow blowing converters, that a want of heat was very much felt, and the metal on many occasions could not be tapped out of the converter. That arose in a great measure from the extreme purity of the Swedish iron melted by charcoal, as compared with the ordinary products of the coke furnaces in this country, and some steps were absolutely necessary to get rid of that difficulty. A very easy method was found. It would be readily understood that when a process lasted some twenty minutes, and a limited quantity of carbon and other materials had to undergo combustion during the whole of the time, while only a given amount of caloric could be produced, they were losing part of it by radiation, and also by heat passing through the sides of the vessel for the whole of the twenty minutes. It occurred to their Swedish licensees that, if they conveyed into the metal a very much larger quantity of air, by using tuyeres with openings one inch in diameter, they would produce heat more rapidly—in fact, burning all their carbon and other combustible matter in eight or nine minutes, instead of spending twenty minutes in doing so—

and would correspondingly lose a much less quantity of heat by radiation, &c. The result of the use of those large tuyeres was, that they got all the heat they could desire, and with a metal of extreme purity (which always set at a much lower temperature) they obtained without difficulty the necessary heat and the metal sufficiently fluid for casting their ingots soundly. Amongst the various ideas which he had found it necessary to put forward to protect himself against those who might invent something to evade his plans, he patented several modifications in which horizontal blowing with tuyeres placed slightly below the surface formed a prominent part of the invention. But there was a great objection to all those fixed vessels having shallow tuyeres. The metal had to be tapped from them, and during that time the process of blowing into the metal was bound to continue in order to preserve the tuyeres from being filled up with the molten metal. This had been, in one way, overcome by the Griffiths mode of passing steam through the tuyeres, instead of air, at the time of tapping. This plan had partially succeeded. But in 1862 he took out a patent in which horizontal blowing took place in a converter mounted on axes, which appeared to be the chief feature in the Robert process. The vessel, being on axes, admitted of placing the tuyeres, on one side at least, at any depth they liked below the surface of the metal. He mentioned in his patent that he placed the tuyeres round the vessel, *or partly round the vessel*, his object being at the time of tipping to prevent any metal flowing into the tuyeres. He therefore preferred to make them surround only a portion of the converter; hence it was evident that, what with the shallow blow so successfully carried out in Sweden, and his own proposals in the side-blowing tipping converter, and some other modifications in which he absolutely blew down on to the metal, but directed a jet so powerful as to plough into or burrow up the metal, and thus use the blast even more shallow than any buried tuyere could do,—with all those modifications, there did not appear to him to be a difference in the proposal of M. Robert that could produce any different results from those that they had obtained, or could obtain, by the older methods. He was therefore disappointed to find that there was no such great novelty in the proposal of M. Robert as could lead to important results; and he fancied that, with the known methods which they had long

had before them, very much the same results would necessarily be obtained as could be obtained with the slightly oval vessel with diagonal tuyeres, giving rotation to the metal with shallow tuyeres blowing horizontally in a vessel mounted on axes.

Mr. A. C. BAMLETT (Thirsk) said there was one point which the Robert process possessed over any other; the castings produced by that process had a property of welding in as easy a degree as wrought iron. As an engineer he had used them, and found them very convenient and economical for large and intricate forgings. He did not know that the same result had been produced by any other process; and if it could be carried out in England, it would be much more convenient than to have to go to Paris, where he had heard that the castings had been produced at a very slight cost, not much more than five or six francs per thousand kilos.

A vote of thanks was, on the motion of the President, passed to Mr. Garrison for his paper.

Mr. GARRISON, in a letter to the Secretary, states that the Robert, or, as it is sometimes called in America, the Bookwalter, converter seems to be meeting with considerable success in the United States. Up to the present date (July 1890), about fourteen converters, ranging from $1\frac{1}{2}$ to 5 tons, had been completed and put in operation. He was not able to state what results had been obtained, but it would appear to be obvious that they must be satisfactory.

It might be of interest, in this connection, to call attention to some points of similarity between the Robert converter and a converter patented by Mr. Daniel Adamson in 1863.*

In his specification Mr. Adamson stated that "the passages (tuyeres) are arranged on one or both sides of the converter, and are placed horizontally or diagonally towards the bottom of the vessel."

As he had previously stated—and a careful consideration of the early history of the Bessemer process satisfied him of the accuracy of the opinion—he could not see where Mr. Robert, Mr. Bookwalter, or whoever it was that devised this form of converter, had sufficient grounds upon which to base any claim of novelty.

* English Patent, December 22, 1863, No. 3233.

THURSDAY, MAY 8TH.

The proceedings of the Institute were resumed to-day—Sir JAMES KITSON, Bart., President, again occupying the chair.

The PRESIDENT, after announcing the order of business resolved upon by the Council, stated that a communication had been received by the Secretary from a gentleman in Canada in reference to their visit to America, which he would ask him to read.

The SECRETARY then read the following letter :—

TORONTO, ONT., *April 28th*, 1890.

J. S. JEANS, Esq.,
SECRETARY, IRON AND STEEL INSTITUTE,
2 VICTORIA MANSIONS, WESTMINSTER, S.W.

DEAR SIR,—I see that your Iron and Steel Institute are going to visit America this Fall, and trust that you and other members will be able to take in Toronto.

If you come this way I shall be most happy to see you, and to show you samples of Canadian iron ores, of which I have specimens from over a hundred different places in the Dominion.

I send you a circular containing some analyses showing that some of our ores are the best Bessemer.

If I am eligible to join your Institute, I should be glad to do so.

In the meantime I shall be much obliged if you can kindly send me the list of your members, particularly those that are coming to America this Fall, and I will send them an invitation to call on me and examine my iron ores.—Yours truly,

T. D. LEDYARD.

The following paper was read :—

ON ALUMINIUM IN CARBONISED IRON.

 BY W. J. KEEP, DETROIT, MICH., U.S.A.

HAVING been invited to prepare a paper on this subject for presentation at the present meeting, we will say at the outset that nearly all results obtained by "Keep's Tests" are *relative*.

We use at all times a test bar, one half inch square and twelve inches long, and we record the actual results of the tests of these bars.

We have shown elsewhere that it is not practicable to reduce results, so as to conform to other dimensions than those of the bar tested.

These tests show strength to resist both weight and impact, deflection, set, and elasticity, for every stress applied. They show where proportionality ceases, give the shrinkage of cast metals, hardness (by a Turner machine), and rigidity.

The tests have been objected to by some because we apply stress transversely, but we desire that such persons shall more fully examine our results.

To make ourselves understood, we present two diagrams, made by our special machines. Fig. 1 is from our weight machine, and fig. 2 is made by our impact testing machine.

Stress is marked on the ordinate *ab*, and strain is measured on the abscissa *ac*.

This test is from our regular run of iron, and we give the record in full.

Size of bar tested by weight, depth .505, breadth .508, length 12 inches.

Shrinkage of this bar, .126 inches.

Shrinkage of a bar cast with it, $\frac{1}{16} \times 1 \times 12$ inches, .154.

Depth of chill, .05.

Fluidity, 7.50.

Ultimate strength (weight machine), 424 lbs.

Ultimate deflection, .22.

Ultimate set, .04.

Ultimate elasticity, .18.

Proportionality ceases at 95 lbs.

Rigidity, 78°; hardness, 35°.

Size of bar for impact test, .502 \times .507 \times 12 inches, broke with a 25-lb. weight falling 2½ inches.

Ultimate deflection, .22.

Ultimate set, .025.

Ultimate elasticity, .19.

The fact of deflection being $\cdot 22$ for both weight and impact is merely accidental, and will seldom occur. It is usually much greater for impact than for weight. Deflection should have been measured at the $2\frac{1}{4}$ blow and as $\cdot 21\frac{1}{4}$ inches.

With a weight of 200 lbs.
Deflection was $\cdot 085$.
Set . . . $\cdot 0075$.
Elasticity . $\cdot 0775$.

With a fall of $1\frac{1}{4}$ inches.
Deflection was $\cdot 135$.
Set . . . $\cdot 01$.
Elasticity . $\cdot 125$.

We tested six bars, and record the average.

Stove Plate Cast Iron, March 28, 1890.—The Michigan Stove Company.

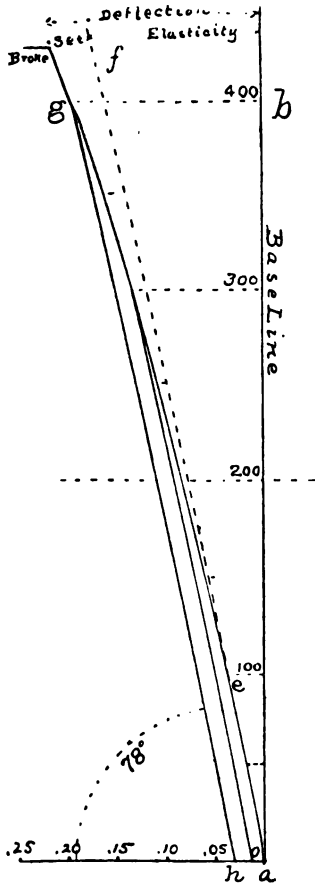


FIG. 1. WEIGHT MACHINE

1889.—i.

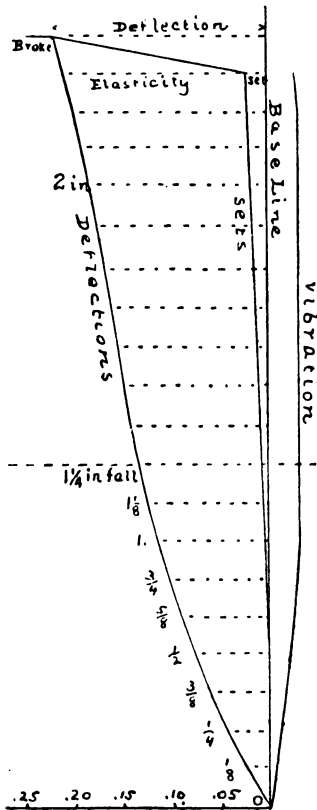


FIG. 2. IMPACT MACHINE

H

The record of perfect rigidity would be the base line or ordinate ab .

No rigidity would cause the form of a material to change without limit on the least application of stress, and the record would be the abscissa ac , perpendicular to ab at the zero point a .

With any material the diagram of rigidity would be a line af , starting at the zero point, and lying between ab and ac . The angle that this makes with ac , when all scales of the diagram are the same as we have employed, indicates the *relative rigidity*.

With some materials this line is a straight line, and with others it is a curve; but in every case, however many times we may repeat the test, the pencil always traces the same rigidity line for a given bar, and we may therefore say that the deflections are proportional to the stresses.

When the bar begins to take set, the diagram leaves the rigidity line, and the point where the lines separate marks the limit of proportionality, and indicates the stress at which proportionality ceases.

After this point has been passed, the diagram records elasticity and set.

Elasticity is the property possessed by matter of regaining its volume or shape after it has been distorted.

Matter is *perfectly elastic* if it wholly regains its original volume or shape, and is *imperfectly elastic* if its recovery is only partial.

The diagram records *total deflection*, which is made up of *elastic deflection* and *set deflection*. If at g , before the ultimate stress has been applied, we remove all stress, and then apply the same stress again, a new diagram hg will be made, which will meet the first at g , the point where the former stress was recorded. The last line hg is the diagram of rigidity, and the angle which it makes with ac is a record of the rigidity of the material. (We always make a rigidity or spring line at 300 lbs.).

By moving this rigidity line, until it starts from zero, it will divide the elastic from the set deflections.

The relative elasticity of the material for any stress is the length of the portion of the abscissa starting from the point marking such stress, and lying between the lines ab and af .

We have endeavoured to give a definition that separates elasticity from the stress exerted to produce a change of shape, and from the work that a distorted body can perform while recovering its former shape.

The elasticity of a body may be increased or diminished along with any variation of strength.

Fig. 2, the impact diagram of another test-bar of the same metal, gives us deflection, elasticity, vibration, and set, for each blow from a 25 lb. hammer, swinging on a six-foot radius, each blow being from a fall of one-eighth, one-quarter, &c., inches.

Having in previous papers treated of ultimate strength, deflection, &c., we propose in this paper to consider the influence of aluminium on iron, as shown by a stress of 200 lbs., which is generally within the limit of proportionality, and for impacts of a fall of one and one-quarter inches, ten blows having been struck from a fall of one-eighth of an inch up to the blow we are to examine.

We will present in tabulated form the results of a large number of measurements taken from diagrams of tests reported in the papers previously referred to. The chemical determinations were made under the direction of Professor C. F. Mabery.

Remelted Wrought Iron (JB) and Aluminium.

Percentage of carbon		0.29	0.32	0.33	0.37	0.30
Percentage of aluminium		0	0.25?	0.58	1.61	2.45
Weight	{ Deflection at 200 lbs. . . . .	.11	0.8 $\frac{1}{2}$	.07	.04 $\frac{1}{2}$	.04 $\frac{1}{2}$
	{ Set . . . . .	.03 $\frac{1}{2}$	.01 $\frac{1}{2}$	.01 $\frac{1}{2}$	0	.00 $\frac{1}{2}$
	{ Elasticity . . . . .	.07 $\frac{1}{2}$	.06 $\frac{1}{2}$	.05 $\frac{1}{2}$	.04 $\frac{1}{2}$	.04 $\frac{1}{2}$
Impact	{ Deflection at 1 $\frac{1}{4}$ in. fall . . . . .	.19 $\frac{1}{2}$	.19	.14 $\frac{1}{2}$	.13 $\frac{1}{2}$	.12 $\frac{1}{2}$
	{ Set . . . . .	.04 $\frac{1}{2}$	.05 $\frac{1}{2}$	.03 $\frac{1}{2}$	.00 $\frac{1}{2}$	.02
	{ Elasticity . . . . .	.15	.13 $\frac{1}{2}$	.10 $\frac{1}{2}$	.12 $\frac{1}{2}$	.11 $\frac{1}{2}$
Hardness		44	44	42	41	30
Rigidity		75	78	82	83	84

Steel containing 1·50 per cent. of Carbon, which is about as high as will be found in Workable Steel.

Percentage of carbon	1·52	1·27	1·19	1·35	1·39
Percentage of aluminium	0·	0·25?	0·87	2·11	2·52
Weight { Deflection in inches	·05	·05½	·05	·05	·05½
Set	0	0	0	0	0
Elasticity	·05	·05½	·05	·05	·05½
Impact { Deflection in 1½ in. fall	·11	·11	·11½	·10½	·12
Set	0	·00½	·00½	0	0
Elasticity	·11	·10½	·10½	·10½	·12
Hardness	40	44	52	50	52
Rigidity	83	83	83	83	83

White Cast Iron containing about 3 per cent. of Carbon.

Percentage of carbon	2·98	...	2·84	3·10	2·90
Percentage of aluminium	0·	0·25	0·54	0·89	1·28
Weight { Deflection in inches at 200 lbs. . . .	·07½	·06	·06½	·08	·08½
Set	0	·00½	·00½	·00½	·00½
Elasticity	·07½	·05½	·06½	·07½	·07½
Impact { Deflection in 1½ in. fall	·12	·13	·13½	·15	·15½
Set	0	0	·00½	·00½	·01
Elasticity	·12	·13	·13	·14½	·14½
Hardness	98	94	96	55	56
Rigidity	79½	82	80	79	78

Grey Cast Iron saturated with Carbon.

Percentage of carbon	3·41	4·09	3·55	3·53	3·45	3·58	3·34	3·10
Percentage of aluminium	0·	0·10	0·14	0·32	0·75	1·50	2·23	3·84
Weight { Deflection at 200 lbs. . . .	·11	·11	·11	·11	·09	·10	·10½	·09½
Set	·02	·01½	·01½	·01½	·00½	·01	·00½	·00½
Elasticity	·09	·09½	·09½	·09½	·08½	·09	·09½	·08½
Impact { Deflection at 1½ in. fall	·14½	·16	·15½	·15½	·15	·17	·16	·15½
Set	·01	·01	·01	·00½	·00½	·00½	·01	...
Elasticity	·13½	·15	·14½	·15	·14½	·16½	·15	...
Hardness	58	60	50	43	39	32	25	41
Rigidity	76	76	76	76	76½	76	76	76

Various Tests with the same White Cast Iron as before.

363. White iron Si 0·08.

471. „ with Si and C made the same as 473.

472. „ with Si and C made the same as 473 with 1 per cent. Al.

473. „ with Si ·60, carbon 2·90, Al 1 per cent. (all estimated).

356. „ with $\frac{1}{8}$ of 1 per cent. of aluminium.357. „ with $\frac{1}{8}$ of 1 per cent. of aluminium.468. „ with $\frac{1}{4}$ of 1 per cent. of aluminium.

469. „ with 1 per cent. of aluminium.

The last two tests are with Robert-Bessemer ingot iron, the iron for each having been caught at the same time; into one ladle was placed a three ounce piece of aluminium.

Number of test	363	471	472	473	356	357	468	469	...	...
Estimated aluminium	0	0	1·00	1·00	0·10	0·25	0·75	1·00	0	0·25	
Weight {	Deflection at 200 lbs.	·07½	·05	·07	·07½	·06	·06	·06½	·07	·06	·04
	Set	0	0	·00½	·00½	0	·00½	·00½	·00½	·00½	·00½
	Elasticity	·07½	·05	·06½	·07	·06	·05½	·06½	·06½	·05½	·03½
Impact {	Deflection at 1¼ in. fall	·12	·11	·12	·12	·11½	·13	·12	·12½	·15	·12½
	Set	0	·00½	·00½	·00½	·00½	·01	·01	·01	·03½	·01½
	Elasticity	·12	·10½	·11½	·11½	·10½	·12	·11	·11½	·11½	·11
Hardness	98	115	70	69	...	...	104	66	45	45	
Rigidity	79½	83	79½	79	81	82	81	80	81	84	

These results exhibit the influence of varying percentages of aluminium upon iron alone, and of the modifying influence of various percentages of carbon, from one quarter of 1 per cent. up to saturation.

We are only considering records at 200 lbs.; ultimate records may show very different results.

The tests with Robert-Bessemer ingot iron show what can be done with one quarter of 1 per cent. of aluminium when the conditions are such as to produce the best results. This and the first set of tests exhibit the influence of aluminium upon commercially pure iron. Such iron is soft, easily bent, and flows readily under stress. Aluminium diminishes deflection by decreasing the set and elasticity. Rigidity is also increased, the grain is closer and more uniform, and the metal is improved in every way when considered as a structural material.

Aluminium softens iron, whether it contains carbon or not. The last cast of remelted wrought iron, containing 2·45 per cent.

of aluminium, made a good weld, and after being forged, bent cold nearly double, and its grain was like that of the finest steel.

While it is nearly impossible to melt and make castings of comparatively pure iron, yet with 2.45 per cent. of Al the metal melted nearly as easily as cast iron, and made good castings in an ordinary green sand mould.

With more carbon, as in the steel series, we find a modification of the results already referred to. The carbon is decreased, the grain is made very uniform and fine, and while the ultimate strength, deflection, and elasticity are immensely increased, yet at 200 lbs. they remain unaffected.

The rigidity is also alike in all. The hardness has slightly increased owing to a portion of the graphite being expelled, and to an increase of the combined carbon from 1.18 in the first to 1.31 per cent. in the last cast.

The indication is, that where carbon is low, aluminium does not change it into graphite, but drives some of the existing graphite out.

(The increased results in the last cast of steel are due to the corners of the test-bar being round, and not to any change in the constitution. This test should therefore be set aside.)

White cast iron will not generally make sound castings; it is brittle, very hard, and takes no set.

The action of aluminium is to decrease the total carbon and to change a portion of what remains into graphite. This latter change reduces brittleness, and therefore increases strength. It allows the metal to bend more with a given weight, and the increase of graphite allows it to take some set. Its hardness is lessened, while its rigidity and elasticity are increased. As a structural material, the metal is improved.

In the series of grey iron castings, where the metal contained all the carbon that it could hold, the natural state of the metal, with 200 lbs. of stress, produced large deflection and set, and low elasticity. Aluminium diminished the total carbon by throwing out graphite, and also decreased the combined carbon.

The latter caused a softening of the iron, while the former increased the strength and elasticity, and diminished set and deflection. Rigidity is not affected. Thus, as a structural material, the metal is improved.

The remaining tests substantiate those which we have more fully considered.

It is very essential that a structural material shall not be too brittle, and the higher the rigidity the better. Rigidity is not brittleness. A material should not take set, because any change of form may imperil the structure.

That a material may not change form, its rigidity must be high, and in order to entirely recover its original form after distortion, it must be perfectly elastic. In such a material proportionality will be high.

Since the first publication of the writer's discoveries regarding the influence of aluminium upon iron, including the fact that it changed combined carbon into graphite, and thereby decreased total carbon, ironfounders have experimented more or less with this metal, and have in almost every case corroborated his statements.

It was, however, overlooked that the results produced might not invariably be desirable.

For example, the superintendent of one of the largest works now making malleable iron castings in the United States reasoned that if it was good for others it must be good for him, and thereupon turned the white contents of one of his furnaces into grey iron, and became convinced that he did not need it.

We have never advocated the use of aluminium in cast iron under existing conditions. We have simply pointed out the results produced by it upon iron, either directly or indirectly, or through its influence on carbon, and have ventured the opinion that if grey cast iron could be made in such a manner that its graphite should be produced by aluminium, instead of by silicon, with comparatively no increase in cost, such iron would be better for most uses.

Our papers on aluminium in iron and in steel show, however, that when it is cheap, or even at the present price (\$2 per lb., 94 per cent. pure), aluminium can be used with great advantage, especially with ingot iron caught directly from the converter.

For more full information regarding this subject the writer refers to his former papers on aluminium in iron, which he has presented to the Institute.

DISCUSSION.

Mr. JAMES RILEY said there was no doubt that the influence of aluminium, whether alloyed with steel or used in connection with the melting of steel, had excited a good deal of interest in the last year or two, during which interval of time he had been frequently pressed to make use of it, and had endeavoured to do so, dozens of times at all events. He confessed that he did not appraise its value so highly as it was appraised by many of his friends. He had not found the effect produced by aluminium to be so great or so valuable as to render it worth while to add a cost in some cases amounting to £1 or £2 per ton to steel. He wanted to use it in connection with the lowering of the melting-point, so that in making steel castings there should not be such risk of hot cracks or ruptures by reason of the contraction which inevitably had to take place, and which existed to a considerable degree in proportion to the temperature at which the metal was cast. Undoubtedly the influence exercised in that direction by aluminium was very considerable. There was one little fact he might mention in connection with this point which was extremely striking. An alloy made up of 20 per cent. of second quality aluminium, and 80 per cent. of steel, which gave 18·3 per cent. of aluminium by analysis, had a specific gravity of 6·23, whereas, had it been the mean of its constituents, the specific gravity would have been 6·89. But the remarkable point about the alloy was that, although it was very fluid at the full heat of the crucible, it set with such extreme rapidity that only one-half of the contents of the pot would run out, and the rest would set on its way out of the pot. This was markedly noticeable in some of the richer qualities, such as $3\frac{1}{2}$ and $4\frac{1}{2}$ per cent. of aluminium, and it might just be observable with $2\frac{3}{4}$ per cent., and so on. An alloy containing some 18 per cent. of aluminium was very short and crystalline, and was of no use as an alloy. That was carrying the use of aluminium to an extremity. The effect produced upon the steel after it was made was not, according to his finding—and he had made some scores of

tests with various quantities of aluminium present—very great. The tensile strength was very slightly increased, not so much, even, as they had found of variation in testing with ordinary steel—that was to say, one might find an addition to the tensile strength which one would expect from a certain steel increased to the extent of, perhaps, two or three tons on the square inch by the addition of a little aluminium. The elastic limit, however, was raised considerably, and that, he apprehended, was the point of which Mr. Keep made so much in his paper with regard to the rigidity of the metal. There was also a slight addition to its ductility. A plate, for instance, made with not more than 1 per cent. of aluminium present had a higher breaking-strain, a considerably higher elastic limit, and more ductility. These points were not ordinarily of so great value in real use as they appeared to be sometimes in making the experiment. He would attribute this circumstance to the same reason as he had given before, viz., the increase of fluidity. One great cause of the cost of steel castings was the very large proportion of scrap which was got. If the heads of the castings, and the gates for them, could be reduced to perhaps 25 per cent., or even to as much as 50 per cent., then the use of aluminium at its present cost might prove economical, and it was in that direction that he was working. He, personally, had ceased to use aluminium a year ago, because the economy was not apparent; in fact, the loss was increased beyond the saving effected in the ways he had named. Lately, again, he had been pressed to resume the use of aluminium. He was told of the important results obtained by people (whom he had never met, by the way) by the use of aluminium, and he had instituted further experiments with it. He got Mr. Packer to go through a whole series of castings, using aluminium in varying proportions, in order to see what results were obtainable, and he would be glad to send the results for the *Journal*.* At that moment his mind was pretty well made up that he would not use aluminium again in connection with the ordinary process of steel-making, but in exceptional practice it might be employed for very thin, small, light castings. In any other respect he did not think that the use of aluminium would prove advantageous to him or to any one.

* The results are published as an Appendix at p. 161^{et seq.}

Mr. J. W. SPENCER (Newcastle) was afraid that he had not much to say, as Mr. Riley had already gone over the ground that he should have covered, and he could endorse most of what he had said—on the subject of steel castings, at any rate. One thing he might add, and that was, that aluminium did not do for steel of all grades of carbon. The more carbon the less its value, and the lower the carbon the greater the value. In its use for the production of castings, of course, there was some considerable advantage obtained by the power of increasing the fluidity of wrought iron or mild steel. He thought, however, it would be found that for steel of higher grades of carbon, it would not altogether come up to anticipation, although for the purposes for which Mr. Riley had used it, namely, for thin intricate, difficult castings, he had no doubt it was very successful.

Mr. RILEY said perhaps he might be allowed to add that the influence of the aluminium in a big charge of 10 or 15 tons began to be dissipated before it got to the end of the charge in the casting. Most of the experiments hitherto made had been dealing with small quantities of metal in crucibles, and there one did not get quite the results that were obtained in dealing with a large mass. There was considerable difference about the effect of the use of silico-spiegel. The use of silico-spiegel was found advantageous, though, of course, not in all the present sizes of charges. At all events the metal remained steady and was easily cast, whereas in the case of the use of aluminium alone, and where silico-spiegel was not used, the casting would become wild and would not set so readily. Another point he ought to have named, and one that was exceedingly interesting, although, perhaps, at present it was not understood sufficiently, was as to the use of aluminium in the making of an alloy. It was not, perhaps, a matter of extreme importance, because it was a thing which was never done, but if an alloy were made of steel and copper, and the resultant metal were examined under the microscope, it would be found that the copper really was not alloyed—it was disseminated all through the piece. If in making that alloy they used some aluminium, they would find a totally different result—the alloy was perfect. Again, in the series of experiments that he had made in connection with nickel, it was found that the most perfect way of

making the alloy of nickel and steel was by the use of aluminium at the end of the charge.

Sir LOWTHIAN BELL, Bart., F.R.S., said he quite agreed in the observations made by Mr. Riley. He happened formerly to have been an unfortunate maker of aluminium; in fact, until recently he had been the only maker of the metal in the United Kingdom. One of the chief uses of aluminium was in making what was known as aluminium bronze. A very extraordinary phenomenon took place when that alloy was formed, which was, that after the copper was melted, and a small ingot of aluminium was plunged into it, immediately the temperature of the whole mass rose considerably, indicative of what might be regarded as a chemical union between the two metals.

Mr. ALFRED ALLEN (Sheffield) said he was inclined to believe that they might very frequently have had traces of aluminium existing in cast iron, and possibly, though not so probably, in steel, without having recognised its existence. Works chemists naturally cut their work as short as possible, and when a sample of iron or steel was sent to a professional analyst he was usually instructed to determine the carbon, silicon, phosphorus, sulphur, and manganese; he had definite instructions as to what he had to do with the iron or steel, and it was very rarely he was given *carte blanche*, and was told, "Now, find out all that is in this sample, whether the information is likely to be of any use to us or not." The result, he was inclined to think, was, that aluminium might often have existed in traces, as what might be called a normal constituent of, at any rate, carburised iron, and had not attracted the attention of those who had analysed the samples. It would be remembered that Faraday, many years ago, found traces of aluminium in a particular class of steel ("wootz"), and Dr. Percy threw cold water on that, and in his well-known work, *Iron and Steel*, rather inclined to the opinion, that it was possibly an analytical error, or that, at any rate, whether aluminium occurred in that particular variety of steel or not, they need not expect to meet with it in English iron and steel. Possibly chemists had been for many years rather misled by that authoritative expression

of opinion. At any rate it was certainly the fact that if they were to count the number of samples of pig iron which had been really carefully examined for aluminium, and in which its presence had been absolutely disproved, their number would be found to be very small. It was known that titanium was occasionally to be found in pig iron, though he doubted whether titanium ever existed in steel. He spoke in the presence of Mr. Riley, who might have an opinion upon that point; but he thought, although it existed in pig iron, it was liable to be eliminated in subsequent processes. He was inclined to think the same of aluminium. At any rate, he would say this from his own experience, that not very long ago he analysed a sample of metal, which might be called refined cast iron, that had been produced by, or rather had been subjected to, a particular process which was intended to introduce aluminium, though, chemically, it did not seem as if the process by which it was treated was well adapted to effect its object, because the aluminium was not introduced in the form of metal; but, at any rate, he could stake his reputation on the fact that cast iron so treated did contain, after the treatment, aluminium in the second place of decimals. There it was in small quantities; therefore they must either assume that the process was partially successful, or that the aluminium pre-existed in the metal before treatment. He did not examine the original iron, but if they had made a careful examination of it he thought they would have found small quantities of aluminium. It was not one of the easiest processes to estimate aluminium in iron. One very good published method (Mr. Stead's) was similar to that which he had been accustomed to use, but some methods which had been employed were extremely fallacious. He had known instances where one chemist had found 2 per cent. of aluminium in a sample of metal where other chemists found no trace at all. There was plenty of room for discussion as to the real proportion of aluminium present in steels having properties attributed to its presence. Some experiments had been mentioned by Mr. Riley where metallic aluminium was introduced into the steel. He might have put it into the steel pot, but it did not follow that it existed in the same proportion, if at all, in the finished metal. It would be just as well to know in all these cases whether the

aluminium was found by analysis, and if so, in what proportion, before they began to argue upon questions of its effect on the physical character of the steel. With respect to the question raised by Sir Lowthian Bell about aluminium bronze, he might state, as an interesting fact, that at the aluminium works at Newcastle they recovered the aluminium which existed in minute shots in the slag by melting the slag with metallic copper.

Mr. EDWARD RILEY (London) could hardly say that he agreed with Mr. Allen, because many years ago he gave his attention specially to the testing of iron for aluminium, and he did not find it. Again, recently he had had on some occasions alloys of iron with aluminium sent to him, and the parties who [sent them were exceedingly indignant with him because he could not find aluminium. He tried to do so very carefully. On the other hand, he had had several samples containing as much as 5 or 7 per cent. of aluminium. In regard to copper, he had had the same thing. People had sent him samples of copper reported to contain aluminium, and he had failed to find any. A young chemist who tested it said that he found 2 per cent. of aluminium, but when he (Mr. Riley) inquired into the matter of how he tested it, he soon found that the probability was that he got silicon from his vessels, and attributed it to aluminium because he did not test what he did weigh to see that it was aluminium. He agreed with Mr. Allen that it was exceedingly difficult to determine very minute quantities of aluminium. He thought it quite possible that aluminium might have been used in a great many alloys of iron, and when it came to be tested the whole of it had disappeared. He would ask Mr. James Riley whether he did not think that aluminium had this effect, that it took oxygen out of the steel, especially cold blown steel or oxidised steel. Was not that the action of aluminium? [Mr. James Riley: "Yes."] Of course, as Mr. James Riley had told them, there was action in another way. It seemed to him that they might use aluminium with any steel, and when they came to test it they might not find aluminium, and yet aluminium might have an effect in the way he had suggested. He had had the same thing with alloys of copper, and he thought that possibly the aluminium might have acted in reducing the

sub-oxide of copper. A great deal was heard about titanium some years ago, and he gave a good deal of attention to it, but he never did find titanium in steel or wrought iron. It did exist in cast iron pretty generally, but it existed in some peculiar graphitic form, and he did not think it would alloy, properly speaking, with iron.

Mr. J. E. STEAD said that during the last year, and for some time previously, he had given very considerable attention, first of all, to the determination of aluminium in steel, and, secondly, to the effects of aluminium on steel. It was more particularly in connection with the determination of aluminium that he then spoke. Remarks had been made by Mr. Riley with reference to aluminium not being present in aluminium steel. He might say that wherever he had tested steel to which aluminium had been added he had never failed to find it, although not to the full extent to which it was added. It was a fact he had found in the course of his experiments, that the aluminium was readily removed by oxidation from the steel. He considered it an utter impossibility for ordinary Bessemer steel or open-hearth steel, or for any steel that had been subjected in any way during manufacture to an oxidising process, to contain aluminium. Even carbonic oxide would oxidise the aluminium out of it in the molten steel, the carbon combining with the iron, and the aluminium passing away as alumina. It was quite possible, in certain steels which had failed to give certain results when aluminium had been added, for no metallic aluminium to actually remain in it; but it was a fact that in cases where he had examined such steel he had always found it. It was probable that some alumina produced by oxidation in the steel was mechanically enclosed in the metal itself, so that an analyst, in testing, would find aluminium as alumina, not as metallic aluminium. It was somewhat difficult to differentiate between the two. He had found alumina in the residue on dissolving aluminium steel in dilute acid, and he believed that it must have existed in the steel in that condition. A short time ago he described, before the members of the Society of Chemical Industry, a method for determining minute quantities of aluminium in steel, and he thought, if those who wished to test alumi-

nium steel would use that method, they would find it capable of giving, in a comparatively rapid way, very exact determinations. It was important that when samples were sent to an analyst there should be a statement setting out exactly what was required. When an analyst received an order to make a complete analysis, it would take him a long period to make it. What with chromium, tungsten, aluminium, and other metals and metalloids being added nowadays, the complete analysis of steel had become a very complicated thing indeed. Hence, when samples were submitted, the constituents to be sought for should be exactly set out. He was very strongly blamed on one occasion for having sent out a steel analysis without showing aluminium. He had not received instructions to determine the aluminium, and the ordinary constituents only were determined. Mr. James Riley had drawn attention to the extraordinary change in volume following the union of steel and aluminium. He (Mr. Stead) had found that if steel with a specific gravity of 7.8 was added to aluminium with a specific gravity of 2.6, they did get a diminution in volume such as they might be led to expect, owing to the chemical combination. In an alloy containing about 23 volumes per cent. of aluminium and 77 volumes of steel, which should have a mean specific gravity of 6.60, the specific gravity was 6.86, or 100 volumes of the material before mixing decreased to 96.3 volumes after mixing.

Mr. R. A. HADFIELD said that, as he had put on the table one or two samples, he would like to make some remarks about them.

Seeing the comparatively small amount of literature on aluminium and its application to iron and steel manufacture, he thought they were much indebted to Mr. Keep for his interesting paper.

Two facts might be mentioned: one of these perhaps might be considered rather heretical; still, he hoped it would be well ventilated, and suggestions made on it.

It had been stated for several years that aluminium lowered the fusion-point of pure iron. From experiments he (Mr. Hadfield) had made on different alloys of iron and steel, this theory seemed to him inaccurate, and offered an insufficient and unsatisfactory explanation as to the fact that the fluidity of molten steel was

increased by the addition of aluminium. It seemed that, whatever increase in fluidity was obtained, it might be due to one of two causes. The first was the oxidation of the aluminium itself, just as silicon oxidised to silica evolved a considerable amount of heat. This might well be so, seeing that aluminium, according to Berthollet, had even higher calorific intensity than silicon. Or—and more probably the true cause—it might be that aluminium, when oxidised to alumina, produced a very fusible slag. One paper often incidentally explained difficult points in another, and he thought that Mr. Galbraith's excellent paper, "On Certain Chemical Phenomena in the Manufacture of Steel,"* gave them the real explanation as to the part played by aluminium. As Mr. Galbraith said on the second page of his paper, though perhaps not having in view specially the influence of aluminium, a metal charged with much oxide of iron, no matter what amount of heat you put into it, will run cold owing to the infusibility of the oxide present. In melting iron and steel there was always present some oxide of iron, and it would therefore seem more than probable that aluminium acted beneficially by reducing this infusible slag and cleansing the molten bath.

That the point of fusion was not lowered, he was able to prove somewhat conclusively, he thought, owing to the kind assistance of his friend M. Osmond, to whom he had sent small samples of aluminium steel, containing 5 per cent. of aluminium and practically no carbon, and whose letter he now had. It seemed such an important point that he hoped he might be excused if he read M. Osmond's letter in full:—

"I carried the heating of your sample by means of the Le Chatelier pyrometer up to 1465°C . At this point slight oscillations of the thermometer" (referring to the spot of light reflected by the galvanometer on to the index scale, and shown in the diagram at the meeting yesterday) "appeared to indicate the approach of the fusion-point; and in fact, after cooling down, I afterwards noticed slight indications on the part of the sample under observation in contact with the tube having become slightly fused. We can therefore suppose the actual fusion-point would be about 1475°C . As ordinary soft steel melts at about 1500°C ,

* See p. 135 *et seq.*

you can see your 5 per cent. aluminium sample had its melting-point only lowered some 25°, or scarcely anything. It is, therefore, absolutely untrue that 10 per cent. of aluminium can lower the fusion-point of iron many hundreds of degrees, as has been so commonly stated." He (Mr. Hadfield) was very glad to have this very clear confirmation of his own belief.

There was only one other fact that he would mention, and it seemed of much interest. He had in his hand a sample of 14 per cent. spiegel. As was well known, this material had a very pronounced fracture; in fact, it was to this that it owed its name. On adding to such molten spiegel about 3 (three) per cent. of aluminium, a very remarkable change took place; the carbon being almost entirely converted from the combined into the graphitic form, manganese remaining practically unaltered. As also pointed out by Mr. Keep, this conclusively proved that the action of aluminium upon combined carbon was very similar to that of silicon. The following gave the analyses of the two samples:—

Analyses of Spiegel before and after Adding Aluminium.

	C.	Gr.	Si.	S.	P.	Mn.	Al.
Before adding aluminium .	4·80	none	...	...	...	13·65	none per cent.
After adding aluminium .	·93	3·45	1·30	·01	·05	11·75	3·19 per cent.

Mr. H. BAUERMAN asked Mr. Hadfield whether in the last experiment there was an actual loss of carbon, and had he determined the carbon in the second?

Mr. R. A. HADFIELD said he had not a complete analysis, but so far as he could see there was very little difference.

Mr. J. E. STEAD said he might state that he had made a similar experiment, and there was not any loss of carbon whatever. Adding the aluminium to pure carbon iron—that was, to iron containing about 4 per cent. of carbon and no silicon, no sulphur, and very little phosphorus—the carbon simply separated out as graphite in the metal. Large quantities of aluminium produced complete separation of a part of the carbon.

Mr. WM. GALBRAITH said he only wanted to touch upon a matter which, so far, had only to a certain extent been drawn

attention to, with regard to the addition of aluminium to iron, either as cast iron, or wrought iron, or steel. He referred to the question of loss. It was pretty certain that in the case of adding aluminium to soft steel from a basic Bessemer or basic Siemens charge there would be a considerable loss of aluminium, and this question, of course, would very seriously affect the cost, and might decide the question whether it should be used or not. But in the case of pig iron probably the loss would not be so great. In fact, they seemed to be in this position, that in the case of pig iron they sometimes got aluminium when it had not been added, and in the case of soft steel and in the "Mitis" castings, &c., they probably added aluminium, and did not afterwards find it at all when it was sought for by analysis. In the latter case, the loss would be caused by the aluminium acting upon the oxide of iron present, thus forming alumina and iron. In some of the analyses given by Mr. Keep, he seemed to have missed that point. For instance, he had referred to a number of cases in which the estimated aluminium varied from .1 to 1 per cent. with Robert-Bessemer ingot iron. He presumed he meant by "estimated aluminium" the amount of aluminium that had been added, but he thought some of the speakers who had just spoken would bear him out when he said that it was exceedingly improbable that in those cases (from .1 up to 3 per cent.) there would be any aluminium present at all, so that the figures in that respect were somewhat misleading. Much depended upon the circumstances in which the aluminium was used in seeking to determine whether the cost was to be such as to make it really useful for its purpose.

Mr. ALFRED H. ALLEN asked if Mr. Galbraith had found aluminium in pig iron where it had not been added?

Mr. GALBRAITH said he had not, and he did not say he had. He thought that that was a question which had been thrashed out a long time ago. Mr. Allen had referred to Dr. Percy's *Metallurgy*, where the question whether aluminium was present in pig iron or not was gone into. It was reduced, of course, from the alumina in the slag, or from the lining of the furnace, if it was present in the pig iron at all, unless, of course, it was actually added.

The PRESIDENT moved that the thanks of the Institute be conveyed to Mr. Keep for his paper. He thought he also ought to add their thanks to Mr. James Riley and others who had given them the results of their experience, particularly as the expenditure entailed by such experiments with a costly metal like aluminium was very considerable. He thought it would save many of them from going over the same ground again, in their anxiety to produce steel of high quality. They were much indebted to Mr. Riley, and to the chemists who had spoken, for the communications they had made to them.

The resolution was adopted by acclamation.

Mr. W. J. KEEP, through the Secretary, observes that, in whatever way the end is accomplished, aluminium seemed to permit of good castings being made from metal which could not be used alone. He might be allowed to repeat what he had published in another paper:—

“We prepared moulds of graphite, and placed in a plumbago crucible 80 lbs. of ‘J. B.’ wrought iron, which was supposed to contain about 0·087 of carbon and 0·056 silicon.

“We placed upon the iron platform near the furnaces containing the steel pots moulds marked 1, 2, 3, 4, and 5.

“It was doubtful whether we would be able to fill the mould No. 1 with melted wrought iron, and much less any of the others.

“We had attached to the ends of four long sticks of carbon, each one inch in diameter, pieces of aluminium. A three-ounce piece for cast No. 2, a seven-ounce piece for cast No. 3, five ounces for cast No. 4, and three ounces for cast No. 5. If we could make each mould take 13 lbs. of iron, these additions would make cast No. 1 contain no aluminium; cast No. 2, 0·25 per cent.; cast No. 3, 1·00 per cent.; cast No. 4, 2·00 per cent.; and cast No. 5, 3·00 per cent. of aluminium.

“The moulds were filled as follows:—After the wrought iron had been in the furnace six hours it was found to be melted and was withdrawn. The first mould was filled, leaving 67 lbs. of iron in the pot. This was set down on the iron floor, and the first stick of carbon was handed to the melter, who stirred in the three-ounce

piece of aluminium and then poured the second mould. This should have left 54 lbs. of iron in the pot. The character of the metal had not materially changed; it had not lost any of its fluidity. The pot was again set down, the seven-ounce piece of aluminium was stirred in, and the third mould poured. The metal had become whiter and more fluid. There should have been 41 lbs. of iron in the crucible, and this was again set down, the five-ounce piece was stirred in, the fourth mould was poured and the pot set down, when there should have been 28 lbs. left. This metal was hotter and more fluid than at any previous heat. After stirring in the remaining three-ounce piece, the iron became still more fluid and more white. When the last mould, No. 5, was poured, 15 lbs. were left, which were poured out on the platform, running into a plate about half an inch thick.

"At each stirring-in of aluminium, not only was the aluminium melted, but the stick of carbon was heated white hot.

"Eighteen ounces of aluminium were melted and four sticks of carbon were raised to white heat, yet the last 15 lbs. were more fluid than the first 80 lbs., which would hardly run.

"The experience with the five casts of steel were exactly the same as the above; and we might add, that with both wrought iron and steel the first two moulds did not fill. The third casting was not only sound, but vent-holes one-tenth of an inch in diameter at each end were filled for a quarter of an inch."

In the fourth cast the metal filled these vents for over half an inch, and in the fifth cast of each series the metal ran up the vents about $1\frac{1}{2}$ inch, and then sank back, leaving a skin on the sides.

The analyses which we have given were made from these first casts.

The physical tests were made from remelts of each of these casts. When the complete results of these tests from remelts were examined, the variation so completely proved the presence of aluminium after remelting, in substantially the same percentages as were found in the first casts, that they did not consider it necessary to analyse the remelts.

ON CERTAIN CHEMICAL PHENOMENA IN THE
MANUFACTURE OF STEEL.

BY W. GALBRAITH, CHESTERFIELD.

ALTHOUGH, from the very commencement of the manufacture of steel by the Bessemer process, oxide of iron was supposed to be present in the blown metal, and possibly to a less extent in the steel itself, yet our knowledge of the presence and character of these oxides is even now of an exceedingly hazy character; and I am quite sure that the important influence which the presence of these oxides has on the metallurgy of iron and steel is far from being appreciated, especially in those later developments of the manufacture of these metals.

Those who have had any experience in the manufacture of *soft* steel by either the Siemens or Bessemer process, and more especially when using a basic lining, must often have experienced the difficulty of keeping such a metal quiet in the moulds, and also of teeming it. It will occasionally get too cold, grow up at the nozzle, and leave a considerable quantity of metal on the sides of the ladle. Moreover, these two difficulties usually go together; that is, the metal which is wild is exactly that which is most likely to set in the ladle.

In order to be able to ascertain the cause, and, if possible, the remedy for this, the following facts should be considered:—

(1.) The difficulty in teeming is *not* due to any lack of heat; *i.e.*, in such a case there has probably been as much heat put on the furnace as it could bear.

(2.) The slag in such a case invariably contains a large excess of oxide of iron, and is blacker and more metallic in appearance than usual.

(3.) There is an enormous evolution of gas.

(4.) There is a larger consumption of spiegeleisen or ferro-manganese than usual before we can get any additional carbon in the steel.

In considering the first fact, I might say that this presents one of the great difficulties found in making basic steel, especially in the Siemens furnace; it has been referred to more than once in the discussions before the Institute, and was prominently brought before us by Mr. Paul (see *Journal*, No. 1, 1889, p. 99), who, referring to this source of trouble, says: "Another condition was, that, with a thin slag containing oxide of iron in excess, it was a matter of impossibility to get heat on the metal."

Now, it is a fact that one heat of steel will teem quite easily, while another will teem with the utmost difficulty, and will leave a large quantity of steel behind, and yet the chemical composition of the two metals may be exactly alike, or, if different, the analysis may be in favour of that which did not teem.

For instance, the steel *A*, of which I append an analysis, teemed quite easily, while nearly the whole of *B* was lost.

	<i>A.</i>	<i>B.</i>
Carbon	·09	·09
Silicon	nil.	nil.
Sulphur	·053	·054
Phosphorus	·049	·062
Manganese	·29	·35

There was a marked difference in the metal, and instead of saying there is "a difficulty in getting heat on the metal," I prefer to say, what I dare say Mr. Paul meant, that there is a great difference in the melting-point of the metals.

It would be, of course, absurd to suppose that the mere presence of a *thin* slag can influence the fusing-point of the metal, and I prefer to suppose that the slag containing an excess of oxide of iron oxidises the metal so rapidly and so effectually that the latter becomes charged with an oxide of iron; that this oxide of iron is one of those lower oxides likely to be produced at a high temperature, and is almost absolutely infusible; and that when the slag is non-oxidising we get the metal free from these oxides, and hence more fusible.

There is everything to justify such an inference, there being abundance of evidence as to the infusibility of steel in the presence of an oxidising slag. Moreover, there are oxides of iron other than the normal and well-known ones; for instance, Sir Lowthian Bell notes the existence of an oxide having the formula Fe_2O ,

which contains one half the oxygen that the normal protoxide does (see *Chemical Phenomena of Iron Smelting*, p. 22). Ball furnace slag from a slag bottom is practically Fe_7O_8 .

The extraordinary infusibility of the protoxide of iron FeO is shown from the following analysis of a puddling furnace bottom, and that in presence of a silicate containing 6.80 per cent. of silica.

	Per cent.
Protoxide of iron	75.54
Peroxide of iron	16.14
Silica	6.80
Phosphoric acid . . . . .	.62
Oxide of manganese . . . . .	.60
	<hr/> 99.70

If such a lower oxide of iron can be formed at all, we have all the conditions of its formation, namely, a very high temperature, a very oxidising basic slag, and a very large excess of the base (or basic material).

In considering the question of the consumption of carbon, it is a well-known fact that, in adding alloys to the ordinary or acid Siemens bath—either spiegeleisen, ferro-manganese, or pig—we practically get the whole of the added carbon in the steel, unless, of course, the tapping of the furnace is delayed.

In the acid or ordinary Bessemer process, the loss of carbon varies as the metal is blown. If well blown down, the loss may be .10 per cent. on the steel, or may be as low as .04 per cent., and this explains why the carbon is not always got with quite the same regularity as in the acid Siemens bath.

In order that I may not be misunderstood here, I may further explain that at the end of an acid or ordinary Bessemer blow the carbon present in the metal is usually about .07 per cent. If alloys are added to give carbon equal to .40 per cent., the result will be .40 per cent., or nearly that figure, and not .47. If the additions are equal to .10 per cent., we get .10 per cent. and not .17 per cent.

In the case of soft steel especially, Bessemer steel is usually very lively, and, on addition of the spiegeleisen, flames very much, due, there is no doubt, to the .07 per cent. carbon being oxidised to carbonic oxide (CO). All this is, of course, well known, and I only wish to point out that the metal can contain oxide of iron equivalent to .07 per cent. carbon when reduced according to the

formula, $\text{Fe}_2\text{O} + \text{C} = \text{Co} + 2\text{Fe}$; i.e., if the oxide of iron is Fe_2O , it will be .74 per cent.

In the basic Bessemer process, the consumption of spiegeleisen is much greater than in the acid process. If .20 per cent. carbon is wanted we have to add about .45 per cent., and this varies (as does also the loss of iron) with the character of the slag, and here we have exactly the same thing again—if the slag contains a large excess of oxide of iron the metal is wild and infusible.

I attribute the difficulty found in making ship steel plates to this fact, that the consumption of spiegeleisen or ferro-manganese is a varying figure, due to the character of the slag, &c.; hence if we aim at .20 per cent. carbon we might only get .17 per cent., or possibly .24 per cent.

I wish to repeat that the heat will not teem, it will be "cold" (?), if the slag is black and metallic, that the loss of spiegeleisen and of the metal itself is then greatest, and that the loss of carbon in such a case (.25 per cent. or more) is equal to 2.66 per cent. of this suboxide of iron (Fe_2O).

We meet the same difficulty in the basic Siemens process, and that to an extent which is not generally admitted; yet, "if you keep your slag as neutral as you can," as Mr. Paul puts it, the metal will teem quite easily, it will lie as quiet in the moulds as any hard steel from the acid Siemens process, and no metal will be left in the ladle. I prefer to use the words "non-oxidising" instead of "neutral," because in such a case the slag is exceedingly basic, while in the acid Siemens process it is exceedingly acid.

I know of no serious attempt in this country to make hard steel by the basic-Siemens process by *means of additions to soft steel*; this can only be successful if the slag is thoroughly non-oxidising, or, better still, by removing it, and proceeding as I describe later on.

As to the evolution of gas, both on the addition of spiegeleisen and on teeming into the moulds, Mr. Müller, in his "Experiments on the Secretion of Gases in Iron and Steel" (see *Iron*, September 14, 1888), finds himself in a difficulty with regard to basic steel, a difficulty which, I think, is explained on the assumption of the existence and decomposition of these oxides; indeed, his experiments are a distinct proof of their existence.

The occluded gas from basic steel (in the solid state) and

from ordinary Bessemer steel are given by Mr. Müller and Mr. Stead, respectively, as follows :—

	From Thomas Steel. "Müller."	Bessemer Steel. "Stead."
	Per cent.	Per cent.
Carbonic oxide	6·00	12·50
Hydrogen	85·40	82·50
Nitrogen	14·30	5·00

The analysis of the gases from the molten metals are given by Mr. Müller as follows :—

	Carbonic Oxide (CO).	Hydrogen.	Nitrogen.	Carbonic Acid (CO ₂).	Oxygen.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Grey Bessemer pig	36·10	55·80	3·60	3·70	·80
Spiegeleisen (7·37 Mn.)	48·1	48·9	2·00	1·20	4·00
Thomas pig	37·10	43·7	14·20	3·30	1·20
Bessemer rail steel	35·50	45·3	11·30	7·00	1·00

	Carbonic Oxide (CO).	Hydrogen.	Nitrogen.	Carbon Dioxide (CO ₂).	Oxygen.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Siemens-Martin metal	36·50	26·70	30·50	1·30	4·70
Soft Thomas steel	60·20	4·80	34·50	·11	1·10
Basic rail steel	67·20	15·80	12·00	4·70	·30
<i>Basic Rail steel—</i>					
First runnings from ladle	81·70	8·20	9·50	·60	...
Last runnings from ladle	54·10	38·60	3·50	3·80	...

It will be noticed that these results are all pretty much alike, with the exception of the basic steels, in which the carbonic oxide is much higher and the hydrogen proportionately low. Mr. Müller finds this a difficulty, and says: "The question forces itself on us why Thomas steel, before all others, possesses the property of absorbing such large quantities of carbonic oxide," &c.

If, however, we assume the existence of the oxides of iron referred to, and that it is only when separated from the oxidising

basic slag that they are decomposed, we can readily account for the large quantity of carbonic oxide which is given off. Indeed, the extra absorption of carbon in the basic process, and the liberation of the extra quantity of carbonic oxide, are about the only evidence that can be adduced as to the presence of these oxides in the molten metal.

There is another disadvantage in having too much oxide of iron in the slag; it is that of loss. Both in the basic-Bessemer and basic-Siemens processes the oxidation of the iron goes on with such a slag much faster than that of phosphorus. If the phosphorus has to be oxidised easily, and without much loss of iron, the slag must contain an excess of lime.

In a comparison of the results from the following slags, *A* being one laid before a previous meeting (*Journal*, No. 11, 1886, p. 75), and *B* being typical of that produced at the Shelton Company's works—

	<i>A.</i>	<i>B.</i>
Silica	9.20	8.20
Peroxide of iron	4.30	1.41
Protoxide of iron	23.60	12.95
Oxide of manganese	2.07	1.61
Alumina	4.10	.25
Lime	42.10	44.23
Magnesia	3.00	5.26
Phosphoric acid	12.30	18.40
Iron	19.55	10.07

—we find that the loss of iron in the slag is much higher in the case of *A* than in *B*, and I assume the phosphorus in the charge to be the same in both cases. As the iron from the added oxides or ores to the charge would probably be more than 3.31 (see below), there would in the latter case be a distinct reduction of the iron from those ores, a result which is borne out in practice.

The comparative results appear thus:—

	<i>A.</i>	<i>B.</i>
Phosphorus in charge	2.49 per cent.	2.49 per cent.
Phosphorus in slag	5.37	8.03
Weight of slag per ton of charge	9 cwt. 1 qr.	6 cwt. 0 qr.
Loss of iron in slag in per cent. of charge	9.00 per cent.	3.31 per cent.

We have thus three advantages in keeping the slag as basic as

convenient. We prevent the formation of the oxides of iron referred to, and consequently cold and lively metal, we enormously reduce the loss of iron, and we produce a slag with more phosphoric acid, and therefore of more value.

We have still, however, the difficulty of controlling the carbon in the steel. However careful, its oxidation is most uncertain. To illustrate the character of this difficulty, the following figures are from samples taken just before the addition of some spiegel-eisen and pig, and immediately after such additions.

	Before Addition of Alloys.		After Addition of Alloys.	
	Carbon in Steel.	Iron in Slag.	Carbon in Steel.	Iron in Slag.
1	Per cent. ·09	Per cent. 10·00	Per cent. ·09	Per cent. 9·65
2	·09	10·80	·09	10·20

	Carbon Percentage Added with Alloys.	Equal to Iron Re- duced from Slag (FeO+C=Co+Fe).	Iron actually Reduced from Slag.
1	Per cent. ·13	Per cent. ·60	Per cent. ·35
2	·13	·60	·60

Further information has been contributed on this point by E. D. Gachter and L. Camperdown (see *Proceedings of the Iron and Steel Institute*, p. 33, No. 1, 1888).

In order to avoid this difficulty with regard to the carbon, Mr. Gilchrist informs us that the Germans add the spiegeleisen in a molten condition *before* the slag comes, but from the foregoing it will be seen that this can only be a somewhat uncertain and partial remedy, and I prefer to proceed somewhat as follows:—

The steel is teemed as usual (with possibly a previous addition of some ferro-manganese) into a ladle with a large nozzle. From this ladle the soft steel, containing, say, ·07 per cent. carbon, is teemed into another ladle, until the basic slag begins to come, when the stream is stopped. While teeming the soft steel into the second ladle there is also run into it sufficient alloys to give

the required carbon, and at the same time there is run into it some siliceous slag, somewhat similar in character to the ordinary Siemens slag. From this second ladle the steel is teemed into moulds in the usual manner.

We thus, by eliminating the tendency to form oxides through the basic slag, get exactly the conditions of an ordinary Siemens-Martin charge, and can make hard or soft steel with accuracy as required.

THE ESTIMATION OF PHOSPHORUS IN THE "BASIC" SIEMENS STEEL BATH.

By W. GALBRAITH, CHESTERFIELD.

ONE of the many difficulties of the "basic" process of manufacturing steel from phosphoric irons consists in the uncertainty of knowing exactly when the phosphorus is low enough without continuing the oxidation longer than is necessary.

In order to ascertain this, it is customary to take a sample from the furnace or converter, and, while hot, hammer it down, quench in water, and then break it. When phosphorus is present in any quantity, the fracture is crystalline and bright, and has a very characteristic streaky appearance. This is, however, not altogether reliable, and cannot be so, as the appearance of the fracture is modified by many things, as, for instance, the size of sample and its thickness, the amount of "work" on it, the temperature at which it is hammered and at which it is quenched, and also the manner in which it is broken. In order to meet this difficulty I have devised the following chemical test, which I have found to be thoroughly reliable and useful.

Dissolve .20 gramme of the drillings in 3 c.c. aqua regia in a small flask, then add about 3 c.c. water and sufficient ammonia to precipitate all the iron, and afterwards redissolve the precipitate in nitric acid, adding it drop by drop until the solution is distinctly clear.

There is now added about 10 drops of molybdic acid solution, prepared according to Fresenius, and the solution is transferred to a small bottle, about 2" high to the shoulder, by $\frac{1}{2}$ " dia., which, after being made up to a definite mark on the bottle, is shaken well.

This is also done with a steel containing a known percentage of phosphorus (say .05 per cent.), and the opacity is compared; and if a number of similar bottles are kept varying from .01 per cent. to .10 per cent. phosphorus, the comparison becomes comparatively

simple. The molybdic acid solution is prepared by dissolving 50 grammes of molybdic acid in 100 c.c. ammonia with 100 c.c. water, this being afterwards plunged into 750 c.c. nitric acid (sp. gr. 1.20).

I can scarcely recommend that a basic Bessemer blow be interrupted long enough for this test, but, as it is done very rapidly, each blow as it is completed might be tested in this way, and any phosphoric heats can thus be detected at once, and before the succeeding blow comes on. There is also the advantage that it disposes of the necessity of the phosphorus being determined in the laboratory for every "blow," as is usually done.

DISCUSSION.

Mr. F. W. PAUL (Steel Company of Scotland) said he should have preferred to have spoken later, and to have heard some of the more learned members first express their views in connection with this paper, as the theory brought forward by Mr. Galbraith, he thought, was a new one, and required a great amount of consideration before it could be accepted.

He thought Mr. Galbraith's assertion in the opening paragraph was hardly flattering to those who had had the management of steelworks for a number of years, when he said that the fact of the presence of oxide of iron was not appreciated. At the Glasgow meeting in 1885, Mr. James Riley, in his remarks on the danger of the "afterblow," said that "in 1875, in making tin-plate bars in South Wales, when they had to go to the verge of oxidising the bath, they found that the smallest trace of oxide of iron present in the resulting steel inevitably spoiled the tin-plate bars;" and as he (Mr. Paul) knew that Mr. Riley expected that statement to be challenged at the ensuing meeting in London, he made an extensive series of analyses of basic steel, which most conclusively proved that, in proportion to the afterblow being prolonged (if there were little manganese present), there was an increased percentage of oxide of iron present in the finished steel. He would not go so far as to say that the analytical method for its estimation was such that the absolute quantities given were correct, but the percentages given would hold good in being comparative all through, and in the cases in which the steel was brittle there was undoubtedly an increased quantity of oxide of iron present in the steel. He was not aware, until he read of it in this paper, that "skulls" or "sets in ladles" constituted one of the great difficulties in making basic steel. His experience of basic steel was on a small scale, but as there were gentlemen present who made it in large quantities, he thought it would be interesting if they would give the results of their experience on this point. The question of sufficient heat before tapping charges from even acid open-hearth furnaces was a practical point necessitating good sound judgment.

When Mr. Galbraith gave the analysis of two charges, A and B—one which teemed and one which did not—he could not see what light that analysis threw on it, nor what was meant when he added that “one might be in favour of the one which did not teem.” Had Mr. Galbraith included in the analysis the percentage of oxide of iron present in the A and B steels, he thought it would have had thrown considerable light on the subject. Last year he said that if a charge of metal were coated with a thin slag, it seemed impossible to get heat in the metal. The absurd suggestion that it was the thin slag that did it was Mr. Galbraith’s, and not his (Mr. Paul’s). With a slag rendered thin by containing excess of oxide of iron, or a slag rendered thin by the presence of lime (acid working), although not containing any excess of oxide of iron, he found the same result took place; the metal did not store up heat as quickly as it would if the slag was more refractory and thicker. If the want of fluidity in the steel was entirely due to the presence of oxide of iron rendering it impossible, one would expect that the furnace would rapidly get hotter, whereas that was not so. He thought there need not be the slightest difference of opinion on that point. Instead of the metal taking up heat, the gas seemed to travel over the tranquil slag, and the heat of combustion in the furnace seemed to radiate away; there was not an actual storing of heat going on. This was not merely a theoretical opinion, but one confirmed by recent acid open-hearth experience in the use of an ore containing an excess of lime, and making a very fusible thin slag. It was a somewhat delicate thing to say that Mr. Galbraith’s conclusions were not correct. He certainly did go as far as that, but he would merely mention these points with the greatest deference, in the hope that they might be of service to the scientists present in enabling them to arrive at a correct solution of the problem. In his own mind, he was inclined to think that it was as much a physical condition as a chemical one.

Sir LOWTHIAN BELL, Bart., F.R.S., said that he had not had that experience in the manufacture of steel that he had had in some other branches connected with the manufacture of iron, but he had paid some little attention to it, and he would just like to say

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one or two words on the first paper read by Mr. Galbraith. In his opening sentence, to which reference had been made, he said, "I am quite sure that the important influence which the presence of these oxides has on the metallurgy of iron and steel is far from being appreciated;" and he went on to say in another paragraph, "It is, of course, absurd to suppose that the mere presence of a 'thin' slag can influence the fusing-point of the metal, and I prefer to suppose that the slag containing an excess of oxide of iron oxidises the metal so rapidly and so effectually that it becomes charged with an oxide of iron." In a third paragraph he said, "There is another disadvantage in having too much oxide of iron in the slag: it is that of loss. Both in the basic-Bessemer and basic-Siemens processes, the oxidation of the iron goes on with such a slag much faster than that of phosphorus." On reading these three sentences one would suppose that the presence of oxide of iron in the slag was the cause of loss, but it was the oxidation of the iron itself which was the cause of the oxide of iron being in the slag, at least according to the view he took of it. What takes place in an ordinary Bessemer converter? The air was blown through the metal, and at first, of course, there was oxidation of silicon and carbon, but, so far as he knew, very little oxide of iron was found. It was only when they began to burn the iron, as it were, in the Bessemer converter that they had oxide of iron in the slag; but instead of the oxide of iron in the basic process being prejudicial to the process, he was inclined to believe that it was the presence of iron in the slag which removed the phosphorus. This was not mere supposition. In the first place, he would ask how the phosphorus was to be got out of the iron and into the slag unless it were first oxidised. He had arrived at the opinion expressed by having carefully analysed the slag, and he found that in the slags there was next to no phosphorus until there was a very considerable accumulation of oxide of iron. Hence he considered that oxide of iron in the slag was an indispensable preliminary of the process.

Mr. J. E. STEAD said there was one very important thing that Mr. Galbraith had possibly forgotten, and that was, that in the early stages of the basic-Bessemer process, the presence of oxide of iron in slag was recognised as being practically a very objection-

able thing indeed. In fact, when basic iron was first produced by Messrs. Bolckow, Vaughan, & Company, under the direction of Mr. Richards, the oxide of iron played such havoc with the metal that it not only removed the carbon from the ferro and spiegel added, but the violent boiling of the bath caused some of the phosphorus removed, and present in the slag, to be precipitated back into the metal. He thought a little explanation upon that point would be acceptable. If by any mechanical agency rich oxide of iron slag was forced below the surface of basic or other steel containing oxidisable bodies, such as carbon, &c., the carbon was oxidised to carbonic oxide gas, and this, passing off rapidly, caused great agitation in the bath, producing continued admixture of the metal and slag, and a consequent rapid elimination of oxidisable bodies.

In the basic-Bessemer process it was at first found impossible, owing to this cause, to retain carbon in the steel, for on the addition of spiegel the oxygen in the blown metal, acting at once on the carbon and manganese, caused such agitation in the bath that the slag and metal were most perfectly mixed, and all oxidisable bodies were removed from the steel by the oxide of iron in the slag. This was not the only disadvantage, for some of the phosphorus removed in the early stages of the process was reduced and passed back into the steel.

It was then seen by Mr. Richards that two courses were open in order to avoid the difficulty. The first was to remove the slag completely, as Mr. Galbraith suggested, but the great practical difficulty of doing this in the Bessemer process prevented it being done. The second was to deoxidise the bath by a substance which would not cause agitation of the metal. As they all knew well, Mr. Richards did this by adding silicon-pig or fluid hæmatite iron. The silicon acted quietly, deoxidising the bath, so that when carbon in spiegel was added, it practically all remained in the steel.

It should be easy to separate the slag in the way suggested by Mr. Galbraith, and to obtain steel of almost any degree of hardness.

There could be no doubt that the basic slag in the open-hearth process was liable to contain too much oxide of iron, and when it did so it was difficult to obtain anything but dead soft steel.

Mr. ALFRED ALLEN (Sheffield) thought they were much indebted to Mr. Galbraith for putting his ideas on paper and bringing them before them. It was only when somebody with courage began to crystallise his ideas in the form of an actual paper, and read it before such a Society as the Iron and Steel Institute, that they began to distinguish between what they believed they knew, what they were sure of, and what they wanted further experiment upon. He was prepared to endorse the statement of Mr. Paul, that it would be desirable and interesting if they had, in the case of some of the specimens referred to in the paper, a knowledge of the actual amount of oxide of iron present. He would suggest that Mr. Galbraith, when revising his paper, would do well to make it a little more clear whether certain expressions referred to the iron or to the slag. In several cases there was some confusion in his (Mr. Allen's) mind as to what Mr. Galbraith was speaking of. With respect to the second paper, he congratulated the author upon having made an advance in the direction of a rapid estimation of phosphorus in steel produced by the basic process. As Mr. Galbraith admitted, they could not stop the basic-Bessemer process long enough to make the estimation; still, it was going in the right direction, and the method would probably be found very serviceable where the open-hearth furnace was used. If the large number of analyses now necessary could be avoided it would be a distinct advance. The process was certainly ingenious, and he supposed it might be termed a "turbi-dimetric" method, since Mr. Galbraith proposed to judge of the amount of phosphorus by the thickness or turbidity the precipitate imparted to the liquid in which it was suspended. He looked forward to the time when they might actually get a rough estimation of phosphorus during the basic-Bessemer process.

Mr. PERCY C. GILCHRIST said his view with reference to the slag it was desirable to have was that the "A" slag was much the best kind of slag, so long as there was phosphorus present to be removed, and that they could not have the slag at this period too full of oxide; but at the end of the operation, when the phosphorus was eliminated, if they wished to have the charge quiet, it was necessary to have a slag lower in oxide and higher in lime;

in fact, a slag similar to "B." At page 137 Mr. Galbraith said he knew "of no serious attempt in this country to make hard steel by the basic-Siemens process by means of additions to soft steel." This statement was not quite correct, as a good deal of basic steel was now being made, low in manganese, and containing from 2 per cent. to 1 per cent. of carbon, by the Darby method. This process was being used by the Brymbo Steel Co., Ltd., and still more largely at the Phoenix Co.'s works in Westphalia, where all the basic rail steel, and a considerable amount of harder steel, was carbonised by this method. The process was operated thus:—At the end of the dephosphorisation sufficient ferro-manganese was added to give 3 per cent. to 4 per cent. of manganese; the product was then filtered through a sufficient weight of carbon to give any carbon that was wanted up to 1 per cent. This process seemed to him to be simple and efficacious, and to be pre-eminently suitable for extending the use of basic steel.

Mr. EDWARD RILEY said they should give their friends on the Continent credit for having adopted this process some years ago. At Dudelange, in the Meurthe-Moselle district, phosphorus was estimated three years ago by this process, and he thought it had also been used at Peiner, the molybdate precipitate being measured in graduated tubes.

Mr. E. WINDSOR RICHARDS said there were two statements in the papers that he disagreed with, and he did not think he should allow them to pass without saying a few words. Taking the second paper first, Mr. Galbraith said, "One of the many difficulties of the basic process of manufacturing steel from phosphoric irons consists in the uncertainty of knowing exactly when the phosphorus is low enough." Then that was followed with a description of the method of ascertaining that point; but he said, "This is, however, not altogether reliable, and cannot be so, as the appearance of the fracture is modified by many things; as, for instance, the size of sample and its thickness, the amount of 'work' on it, the temperatures at which it is hammered and at which it is quenched, and also the manner in which it is broken." He imagined that no steelmaker with any common-sense would

first for one blow take a few pounds of steel, hammer it flat, and judge its appearance; then take a sample of 50 lbs. of steel, hammer it, and expect to be able to judge by the fracture whether the phosphorus was low enough. Having made very many thousands of casts from the basic-Bessemer converter, it had been his practice to take the *same-sized sample always*. With a ladle he took a sample of a few pounds, and immediately poured it into a very small ingot mould, always of the same size, and as soon as the molten steel was set it was hammered flat, and two or three minutes were quite sufficient to perform the whole operation; and he contended that he did know absolutely, judging by the fracture, within a few hundreds of a per cent. what the phosphorus was. They might afterwards have to fall back upon Mr. Galbraith's analysis, but they would be none the better for it, because it would take so long a time that the cast would be lost if it did contain too much phosphorus, so that he really did not see the value of it to manufacturers of basic steel. At page 137 there was another point to which he took exception. The author said, "In it" (the basic-Bessemer process) "the consumption of spiegeleisen is much greater than in the acid process." He (Mr. Richards) said the percentage of spiegeleisen used was 50 per cent. less. That was a very great difference. Mr. Stead mentioned the question of rephosphorisation, which was their early trouble in making basic steel. He ascertained that by the addition of a small quantity of silicon the molten metal was rendered quiet, and spiegeleisen could then be added without rephosphorisation. Supposing it was necessary to put in 8 per cent. of spiegeleisen in an ordinary Bessemer charge, it would only be necessary to put in 8 per cent. of hæmatite pig iron, containing about $3\frac{1}{2}$ per cent. silicon and spiegeleisen; that is, 4 per cent. of Bessemer pig iron and 4 per cent. of spiegel. The effect of the silicon in the pig iron was to quiet the metal, and then by the addition of only 50 per cent. of the usual quantity of spiegeleisen, the bath being perfectly quiet, there was no oxidation of the manganese. Consequently they found nearly the whole of the manganese in the steel. This explained the reason why he took exception to the paragraph in which Mr. Galbraith said the consumption of spiegeleisen was much greater than in the ordinary process.

Mr. J. E. STEAD said, on reading Mr. Galbraith's second paper, it struck him that his process was a perfectly new method, and likely to give a very good and rapid result. He might remark, after what Mr. Riley had said, that Professor Eggertz many years ago—in fact, in his (Mr. Stead's) very early days—brought out a process of measuring the actual quantity of precipitate in a small tube. The German method referred to by Mr. Riley was a modification of that. In Mr. Galbraith's process, a minute quantity of the precipitate suspended in the liquid could be more readily measured than when concentrated at the bottom of the tube. He used a minute quantity, two-tenths of a gramme of steel, on which to make an analysis. In the precipitate measuring processes the quantity required was much larger, and the time of manipulation considerably greater, and differed altogether from Mr. Galbraith's process.

Mr. GALBRAITH (in reply) said he confessed he did not think it possible in a reasonable time to reply to all the objections and questions that had been raised with regard to his two papers, even if his notes had been of such a character as to follow them throughout. With regard to what Sir Lowthian Bell said, he thoroughly agreed with him. Oxide of iron was absolutely necessary. Unless they had the oxide of iron there would be no oxidation, and the process could not be carried on at all. At the same time, the object of his paper was to point out that if they got a large excess of oxide they would get an oxidation beyond what was necessary. The carbon was oxidised very rapidly, and then the metal itself was charged with oxide of iron, which, unless it was got rid of in some way, or prevented from being present, would affect the teeming and after-treatment of the metal. In reply to Mr. Windsor Richards, he might point out that the process in question was devised for the basic-Siemens process, and not for the basic-Bessemer. In the former case there was abundance of time to make the test, which only occupied a few minutes. It was only with reference to the basic-Bessemer process that he had any doubt as to the length of time. Of course, no one would think of taking at one time 1 lb., and at another 50 lbs., to make a mechanical test, but his contention was

that so much depended on the circumstances mentioned—all of them influencing the appearance of the fracture to some extent—that there was a risk of their neglecting to blow down sufficiently. A moment or two's blowing, indeed, made all the difference. In the basic-Siemens process, however, there was more time, and as the mechanical test referred to failed to indicate the smaller quantities of phosphorus, the chemical test which he had described had been very valuable. He did not say that in the basic-Bessemer process the mechanical test was objectionable. If the metal was of a proper character, there need not, with care, be much fear of over-blowing. He was astonished at the remarks of Mr. Paul. A great deal that he said was, he thought, due to a misapprehension—which possibly was due to his (Mr. Galbraith's) own fault—of what he was aiming at. Mr. Paul stated that the absurdity of supposing that the thinness of the slag would influence the fusing-point of the metal was his (Mr. Galbraith's). Well, it was his; but he went on to say that with a thin slag they could not get heat on the metal, and not even on the furnace. His (Mr. Galbraith's) contention was, that they could get it on the furnace—that with a very thin slag, a slag which was like a sea of glass, they could burn the furnace down, and yet the metal would not teem. That was his experience, and he could not understand Mr. Paul's statement. Where did the heat go to if plenty of gas and air in proper proportions were passed into the furnace? The heat must go somewhere, and Mr. Paul himself, in the place he (Mr. Galbraith) referred to,* stated that it was a question of slag after all, and that if the slag went wrong they got the chequer-work all wrong too. That was the same thing that he was referring to—they got a large excess of oxide of iron with the slag, and this oxide of iron volatilised or sublimed, and got into the chequer-work, which it fluxed. At all events something of that kind must happen. Mr. Gilchrist had said that the "A" slag, containing the larger quantity of oxide of iron, was a very good slag to work the metal with, but not to finish off with. He might say that he believed that the "A" slag was one which was finished off with. It was not his, and he was not objecting to it particularly, further than that he thought that such a slag would have a tendency to do

* See *Journal of Iron and Steel Institute*, No. I. 1889, p. 101.

what he had said, and he thoroughly agreed with Mr. Gilchrist that it was a proper slag to work the charge on, but as they went on towards the finish it was necessary to have a little more lime to check the oxidation. It was necessary to have a considerable quantity of oxide of iron in the early stages or they could not get oxidation to go on.

In regard to Mr. Darby's process, which Mr. Gilchrist had referred to, he had no experience with it, and his difficulty about it was whether it was possible to get the carbon with any great regularity. Possibly the conditions under which the process was carried out might entail such a difficulty, but that at present was the drawback about it. Mr. Riley had informed him that the Germans were carrying out his (Mr. Galbraith's) process of determining the phosphorus in the bath. It might be so, but, of course, he was not aware of it; and if he had known that it was being done elsewhere he would never have described it before the Institute.

The PRESIDENT thought they would all agree that Mr. Galbraith had given them two valuable contributions. They had led to an excellent discussion, and their thanks were due to the author for his papers. He proposed a vote of thanks accordingly.

A vote of thanks to Mr. Galbraith was then accorded by acclamation.

ON THE ROLLET PROCESS FOR PRODUCING A PURE CARBIDE OF IRON.

BY A. ROLLET, ST. ETIENNE (FRANCE).

Pig iron or castings, steel and iron, generally contain more or less sulphur, phosphorus, silicon, and other substances, tending either to improve or to deteriorate their qualities. Sulphur and phosphorus are usually the only impurities that are taken into consideration in castings of steel or of iron.

In refining so-called pure pig iron for making iron or steel in the presence of an acid slag by any of the ordinary processes, products are obtained which retain the greater part of the sulphur and all the phosphorus contained in the pig iron treated. It even happens in the Siemens furnace that the refined (decarburised) product is more sulphurous than the bath at the commencement. When phosphoric pig iron is refined for iron or steel in the presence of a basic slag by one of the ordinary processes, the products obtained contain much less phosphorus than either the castings or the bath at the commencement. They retain, however, a notable portion of the sulphur.

In either case, the iron or steel obtained is of mediocre or indifferent quality.

It is, moreover, well known that steels obtained in the presence of an acid slag have special qualities, different from those of steels containing the same percentage of sulphur, phosphorus, and other impurities obtained in the presence of a more or less ferruginous basic slag, and that crucible steel, which is obtained in the presence of the most acid and least ferruginous of all slags, possesses properties peculiarly its own.

Therefore special steel, such as is employed in certain industries, *e.g.*, for the manufacture of ordnance, tools, &c., is preferably, or rather exclusively, made by melting on an acid bottom (or hearth), or in crucibles, such pure materials as are comprised in the same category as charcoal irons and the best brands of Swedish iron.

The process of purifying pig iron, as here described, is intended to be auxiliary to the manufacture of special qualities of steel, its object being to eliminate sulphur, phosphorus, and silicon from the castings. It consists in melting pig iron, and maintaining it at a very high temperature under a double action, slightly reducing and slightly oxidising, in the presence of a slag obtained by admixtures of limestone or lime, iron ores, and fluor-spar, in proportions depending on the quality of the pig or castings employed.

The apparatus I employ for this purpose is a blast-furnace or modified cupola, using coke and hot blast. The burdens are introduced in the same way as in blast furnaces and cupolas.

It consists of a part A, an independent shaft C, several rows of tuyeres F.F.F., a siphon arrangement SS for separating metal from slag, and a front chamber M.

Externally, it is composed of sheet iron and steel; internally, at the bottom it is lined with any suitable refractory material, preferably with magnesia. It is cooled externally at all parts liable to injury by currents of cold water.

The tuyeres are arranged in several rows, above one another. They are water tuyeres, and project into the furnace. The hearth is situated as near as possible to the lower row of tuyeres. A single hole, K, serves for tapping both the metal and the slag together, as the case requires. When in working order, the metal is separated from the slag by means of the siphon SS, which is so arranged in relation to the hole QO as to prevent the blast from blowing through. The metal flows out at LSS, and the slag at QO.

The tuyeres are arranged in several rows, to facilitate the melting of all the substances charged. They are arranged one above the other, so as to raise the temperature along a line passing in front of their nozzles, and so ensure good working. They project inwardly, so that their ends may not get clogged by the colder and more decarburised matters which descend along the walls.

The approximation of the lower row of tuyeres to the hearth is intended to prolong the action of the blast upon the slag, which at that point is light and frothy, and upon the metal which flows down through it, so as to ensure a greater elimination of phosphorus. The separation of metal from slag, as soon as both are removed from the action of the blast, is carried out so as to prevent

the phosphorus already eliminated from going back into the metal, a result which would be produced by the reduction of the phosphoric acid of the slag by the action of the coke and the metal. Another object of the separation is to prevent too great a recarburisation of the metal.

The temperature of the blast is as high as possible, viz., 400° at least, so as to ensure the good action of the tuyeres. These would otherwise get clogged by the slag, which is always very refractory and stiff, or by the decarburised metal which forms at their ends.

The furnace being in operation, metallic iron is formed, by the action of the blast and the iron ore upon the cast iron or pig, on the bottom part of the walls, where it adheres, thus forming, after working twenty-four to thirty-six hours, a substitute for the original lining. The furnace may thus be run for an indefinite period of time. But it will be preferable, after two or three months' working, to reline the upper portion, as the bricks will then be worn out by attrition.

The production is from 50 to 75 tons per day of twenty-four hours. The product obtained usually has a white, spongy appearance. The slags are yellowish white. They contain almost all the phosphorus eliminated from the cast iron or pig in the state of phosphoric acid, and only a part of the sulphur in the condition of sulphide.

The elimination of the sulphur is complete up to 99 per cent., and even more. That of the phosphorus amounts to 80 or 85 per cent., in exceptional cases to 90 per cent., and more. And as the recarburising action of the coke sets a limit to the decarburisation of the cast iron, a casting once treated may be treated again in the same manner; by which means, beginning with any sort of castings, a carburised iron purer than the best Swedish iron used for cementation can be obtained.

The carburised iron thus obtained may be used in Siemens furnaces with acid bottoms, where it may be employed to a greater extent than cast iron or pig, and so diminish the weight, if wrought iron be required. It may be puddled, in order to produce iron destined for melting on acid bottoms, for crucible melting, or for cementation. It can also be used as cement steel for crucible melting, mixed with iron.

DISCUSSION.

Mr. HUGH BELL said if he had been in possession of a print of the paper earlier he might have been able to offer some figures which would have been of interest. He was obliged to speak entirely from memory, not having the figures to which he wished to refer, but he might say that they had been doing at Clarence precisely that which Mr. Rollet described, and with the same object in view. He was afraid they had not as yet attached such importance to the process as Mr. Rollet did. They found that they did get rid of a considerable part of the sulphur—not an unimportant result to attain. With regard to the phosphorus, little or nothing disappeared, but, speaking off book, with regard to silicon a large portion went. He had no doubt that in a cupola better constructed than the very temporary and experimental apparatus which they had at Clarence, the operation could be carried on much in the way and with the results, as to quantity per day, spoken of by Mr. Rollet. It seemed desirable to show that other minds were travelling in the same direction as Mr. Rollet was travelling, with results not very greatly differing from his, but without that sanguine hope of a successful issue to which his paper seemed to point.

Note.—At the suggestion of the President, Mr. Bell appended the following analysis of casts made in September 1889, cold blast being used in the cupola, lined with Chrome ore:—

Pig Iron Treated.	Resulting Metal.					
	1.	2.	3.	4.	5.	6.
Ph . . . 1·60	1·46	1·41	1·34	1·24	1·18	1·08
S . . . 0·08	0·013	0·028	0·032	0·013	0·024	0·017
Si . . . 1·80	0·420	0·220	0·600	0·520	0·59	0·739

The PRESIDENT said Mr. Rollet was not present to reply, he being in St. Petersburg, but he was sure the meeting would wish

the Secretary to convey their thanks to him for his contribution. That concluded the business of the day, but before they separated he desired to move—"That the best thanks of the Iron and Steel Institute be, and are hereby, tendered to the President, Council, and Secretary of the Institution of Civil Engineers, for the free use of their rooms, and for the facilities otherwise accorded for the present meeting."

Sir H. BESSEMER, F.R.S., said he was very happy to second that proposition. The Institute, as they all knew, had from year to year had the advantage of that theatre for their meetings, and he was sure that they all felt deeply indebted to the Institution of Civil Engineers for their continued politeness and kindness.

The resolution was adopted.

Earl GRANVILLE, K.G., said he had had a very great pleasure conferred upon him, namely, to propose a vote of thanks to the President. In such an assembly, it was unnecessary to say anything about Sir James Kitson. It required a good many years, besides character and ability, to build up the sort of reputation that he had among his fellow-citizens. With regard to his conduct in the chair, he (Earl Granville) was in this unfortunate position, that on the previous day he was, to his great regret, prevented from being present, and therefore he could only speak upon hearsay evidence, but he had relied for a good many years on the word and judgment of his neighbour, Sir Lowthian Bell, and he had assured him that the President's conduct in the chair had been admirable. If they differed from that view they would reject the vote. In the meanwhile he had the courage to propose it.

Mr. HUGH BELL said he had the honour to second the vote just submitted to the meeting. He was glad to be able to assure his Lordship that he had no need to fear as to the result which would follow when it was put to the vote. He did not speak from hearsay. He had sat under the President on more than one occasion, and perhaps the meeting would allow him especially to allude to his Presidency in Paris, where, of all the Presi-

dents they had ever had, Sir James discharged very difficult and onerous duties in a way which marked him out as one of the most successful. He would like to say that, in submitting this motion, they were not only grateful for the favours that were past, but, in the true sense of the word, they were expressing their lively sense of favours to come. They were not forgetful that Sir James was not occupying the chair for the last time during his term of Presidency, but that they were looking forward to the performance of his duties in another country, which could hardly be regarded as foreign, namely, America, in the autumn. He was quite certain that they would most cordially render to him their thanks, and he had great pleasure in seconding the resolution proposed by Earl Granville.

The resolution was agreed to.

The PRESIDENT said he was much obliged to the meeting. His Lordship, with his well-known prudence, had perhaps not referred to his experience of his (Sir James Kitson's) chairmanship at other meetings, because he had had the honour and pleasure of meeting his Lordship in other places where perhaps he had not to control gentlemen of scientific and refined habits, but a much more turbulent order of men. He believed his Lordship had in the past given him some credit for being able to control those elements which were wanting in the present meeting. He had to ask them to return their thanks to him by their support at the meeting in the United States. As he had previously announced, they were promised a very remarkable reception. The American iron and steel trade acknowledged its great indebtedness to the United Kingdom for information it had received, for inventions which had been developed, and for communications that it had obtained through the members of the Iron and Steel Institute. The promise was so great that, last evening, Sir Henry Bessemer expressed his anxiety to go with them. He (the President) would require their support, and he fully counted upon it.

APPENDIX.

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1889.

RECEIPTS.		EXPENDITURE.	
To Balance on December 31, 1888—		By Salaries of Secretary and Clerks	£718 0 0
Invested	£4997 12 8	" Office Rent, Cleaning, &c.	332 15 11
On Deposit with N.P. Bank of England	998 3 6	" Purchases for Library and Office Furniture	30 1 4
	£5995 16 2	" Editing and Translating	191 13 0
Entrance Fees	£245 14 0	" Expenses in connection with Annual Meeting in London, May 1889	46 9 8
" Subscriptions	2759 8 0	" Expenses in connection with Meeting in Paris, September 1889	264 5 3
" Journals sold	181 15 0	" Journal Publishing Expenses	775 6 7
" Interest	253 13 2	" Printing, Advertising, and Stationery	265 11 11
	3442 10 2	" Postages, Receipts, &c., per Treasurer and Secretary	1 2 6
" Balance due to Treasurer.	360 0 9	" Sundry Payments	93 19 4
		" Special Bazaar Medal and Diplomas for Medallists	56 1 6
			29 0 0
			£2794 12 2
		" Investments—	
		In £1170 North-Eastern-Darlington 5½ per cent. Stock, at a cost of	£1738 8 9
		In £1081 North-Eastern 1876 Preference Stock, at a cost of	1998 19 7
		In £1346 Scinde, Funjaub, and Delhi 5 per cent. Stock, at a cost of	1999 0 7
		In £760 Great Indian Peninsula Railway 5 per cent. Stock, at a cost of	1267 6 0
			7003 14 11
	£9798 7 1		£9798 7 1

DAVID DALE, *Hon. Treasurer.*
 DARLINGTON, April 15, 1890.

* This has since been compulsorily converted into an Annuity up till 1958, with a Sinking Fund to replace the amount of Stock, £154c.

*APPENDIX TO MR. JAMES RILEY'S REMARKS ON
MR. KEEPS PAPER (p. 121).*

**RECORD OF EXPERIMENTS MADE IN THE ALLOYING
OF STEEL AND ALUMINIUM.**

The experiments of which the details are here recorded were made at the works of the Steel Company of Scotland (Limited), Hallside, near Glasgow, under the personal supervision of Mr. Packer, chemist, &c. The aluminium used in the experiments was of the following composition:—

Aluminium	95.5
Iron	2.51
Silicon	1.85
Carbonaceous matter . . . . .	.20
	100.06

Under tensile test (in the cast state) the results were 8.7 tons breaking strain, 10 per cent. extension in 1 inch, 5 per cent. in 4 inches, with contraction of area 2.5 per cent. Fracture amorphous. We tried to roll a piece of this metal cold, but it split the first pass through the rolls.

A piece of first quality metal was then tried, containing 99½ per cent. aluminium, ½ per cent. silicon and traces of iron, with the following results:—

Cast aluminium of 99½ per cent.—Elastic limit, —; Breaking strain, 7.9; extension in 4 inches, 18 per cent.; contraction of area, 27 per cent.

Rolled aluminium of 99½ per cent. (½-inch plate).—Elastic limit, 1 ton; breaking strain, 8.0 tons; extension in 4 inches, 34 per cent.; contraction of area, 73 per cent.

The fracture of the rolled metal was silky; of the cast metal amorphous. The cast piece stretched very equally all along its length.

Composition of the charges.—This series was made in plumbago pots, lined with silica, and consisted of 76 lbs. of fine steel scrap, 1890.—i.

and 4 lbs. of Swedish pig iron, with an addition of 0.25 per cent. of 80 per cent. ferro-manganese at the end.

The pig iron was charged in the bottom of the pot with scrap above, aluminium was added at the end in varying proportions, and when thoroughly melted and incorporated with the contents of the crucible, by stirring, the charge was immediately poured into moulds, and tests made as hereafter described. Aluminium was the only variable addition.

Analytical Results.

Test No.	95 per Cent. Quality Al. added per Cent. of Initial Charge.	Per Centage Pure Al. in Total Charge.	C.	Si.*	S.	P.	Mn.	Al.	Loss of Al. per Cent.	Spec. Gravity.		Remarks.
										Cast Metal.	Wrot. Metal.	
A. 1	Nil	Nil	.28	.17	.027	.025	.50	Nil.	Very bridling loss, if any. The differences are within the errors of experiment.	7.15*	7.84	*Very spongy hence low result.
2	.05	.0475	.27	.08	.028	.025	.58	Not det.		7.81	7.83	
3	.10	.095	.29	.07	.025	.025	.51	„		7.79	7.81	
4	.25	.237	.30	.10	.023	.027	.40	.23		7.78	7.79	
5	.50	.47	.24	.12	.025	.023	.54	.45		7.73	7.77	
6	1.00	.935	.28	.15	.020	.023	.50	.95		7.70	7.72	
7	2.00	1.87	.20	.20	.022	.023	.45	1.80		7.62	7.67	
8	3.00	2.76	.20	.23	.02	.022	.50	2.75		7.44	7.58	
9	4.00	3.64	.23	.20	.02	.023	.47	3.60		7.35	7.48	
10	5.00	4.52	.20	.18	.02	.022	.50	4.6		7.27	7.40	
B. 8	3.00	2.76	.30	.22	.023	.025	1.25	2.70		7.45	...	Higher Mn.

* The silicon is derived mainly from crucible, but also from aluminium, which contains 2 per cent. nearly. The specific gravity of the alloys is less than the mean of their constituents. An alloy made up of 20 per cent. second quality aluminium, and 80 per cent. of steel, showing 18.3 per cent. Aluminium, by analysis, gave specific gravity 6.23, whereas, according to the mean of its constituents, it should have been 6.89.

Tensile Results of Cast Metal Annealed.

Test No.	Size of Tensile.	Elastic Limit.	Breaking Strain.	Ext. 4 ins.	Cont. Area.	Fracture.	Size of Bend Test.	Bend and its Fractures.
A 1	$\frac{3}{4}$ dia.	...	...	...	...	No tests as cast ; metal not solid	...	...
2	.92 dia.	16.5	30.7	7.8	8.5	Grey amorphous	1" sq. bar	{ 90°, and broke, fracture amorphous grey.
3	"	17.4	34.0	11.7	14.4	" "	"	{ 49°, and broke.
4	.64 dia.	15.8	38.6	14.0	13.5	" "	"	{ 30°, grey amorphous fracture.
5	.90 dia.	15.7	35.4	19.0	17.0	" "	"	{ 70°, and broke.
6	.64 dia.	16.0	35.0	13.0	15.0	" "	"	{ 30°, (II.) 30°, crystalline fracture.
7	"	17.0	34.5	13.0	17.0	{ Partly amorphous, partly crystalline	{ "	{ 70°, crystalline, one corner spongy.
8	"	16.0	33.0	10.0	Nil	Very crystalline	"	{ 55°, and broke, very crystalline.
9	.58 dia.	17.0	32.6	2.5	Nil	" "	"	{ 40°, and broke, very crystalline.
10	.90 dia.	16.0	32.1	3.1	Nil	" "	"	{ 15°, and broke, very crystalline.
B. 8	.83 dia.	20.0	40.0	8.5	Nil	" "	"	{ 25°, and broke.

Summary of Results of Tests of Castings.—Up to No. 6 the breaking-strain very good, and exceeds ordinary metal by about 2 per cent., except No. 2; No. 7 is also rather higher, while the rest run much about the same. The extension, up to No. 7, is good; No. 5 is very good; No. 8 is a fair extension, but otherwise very unsatisfactory; No. 10 is very poor.

Tensile Tests of Rolled Pieces.

Test No.	How the Metal Hammered and Rolled.	How Treated.	Size of Plate.	Elastic Limit.	Breaking Strain.	Ext. 4 inches.	Ext. 8 inches.	Cont. Area.	Fracture.
A 1.	Fairly, a little loose on edges, otherwise good	As rolled. Annealed.	$\frac{1}{8}$ " " " " " " " "	18.0 14.6 25.5 25.6 17.5 18.3 21.0 24.7	34.3 29.4 42.8 37.7 38.6 37.2 46.75 42.75	22.0 25.9 14.8 22.7 24.9 29.2 14.0 16.5	17.5 22.8 12.75 20.0 16.6 24.6 12.0 15.2	Per Cent. 42.6 48.7 25.0 33.7 39.8 40.6 31.8 34.4	Silky. Silky. Irregular silky. Irregular silky. Irregular silky. Diagonal silky. Diagonal silky. Cupped silky.
A 2.	Hammered and rolled well	As rolled. Annealed.	" "	25.5 25.6	42.8 37.7	14.8 22.7	12.75 20.0	25.0 33.7	Irregular silky. Irregular silky.
A 3.	Hammered and rolled well	As rolled. Annealed.	" "	17.5 18.3	38.6 37.2	24.9 29.2	16.6 24.6	39.8 40.6	Irregular silky. Diagonal silky.
A 4.	Hammered and rolled very well	As rolled. Annealed.	" "	21.0 24.7	46.75 42.75	14.0 16.5	12.0 15.2	31.8 34.4	Diagonal silky. Cupped silky.
A 5.	Hammered and rolled well	As rolled. Annealed.	" "	22.2 20.0	38.5 36.6	21.0 22.5	18.1 20.3	36.9 41.0	Diagonal silky. Irregular silky.
A 6.	Hammered and rolled well	As rolled. Annealed.	" "	20.2 ...	42.5 40.75	12.5 15.6	12.5 12.75	20.0 27.5	Irregular silky. Diagonal silky.

General Tests.

Test No.	Relative Fluidity, No. of Inches run.	Amount of Piping in Special Ingot, Maximum Length Measured.	Amount of Contraction on Cooling, Measured on 12-Inch Exact.	Appearance of Skin of Bar Cast in White Sand.	Colour and Appearance of Metal generally, and Remarks.
	Inches.	Inches.			
1	1.75	Nil honey-combed.	.25-inch bare	Good.	Usual blue colour.
2	1.75	5 $\frac{3}{4}$	.25 "	Good.	{ Usual blue colour, piping narrower; hence, longer than the others.
3	9.5	4 $\frac{1}{2}$	.25 "	Good.	{ Still blue, but a shade lighter.
4	1.0	4 $\frac{1}{2}$	.25 "	{ Very good, best of all.	{ Still blue, but a shade lighter.
5	3.5	4 $\frac{3}{4}$	.25 "	Fair.	{ Still blue, but a shade lighter.
6	5.5	5 $\frac{1}{4}$	.22 "	Good.	{ Getting whitish in appearance.
7	0.5	5 $\frac{3}{4}$	.25 "	Good, flaky.	{ Getting still whiter.
8	3.0	4 $\frac{3}{4}$	.225 "	Very flaky.	{ Very light coloured and iridescent.
9	6.75	5	.2 "	{ Good, but flaky.	{ Still lighter and iridescent.
10	1.0	6 $\frac{1}{4}$	.2 "	Very flaky.	{ Very light colour, almost white, and iridescent.

The surfaces of the ingots were good up to No. 5, No. 4 being the best, but much the same as ordinary steel. In No. 6 and onwards the surfaces were decidedly poor and inferior to ordinary steel.

Beginning with No. 6 (1.0 per cent. aluminium), there was a scum (of oxide, Alumina) formed on the metal, which increased with each successive addition of aluminium, and became interspersed amongst the metal, causing it to *set in layers*. It was decided with Nos. 7 and 8, and very marked with Nos. 9 and 10, and was the cause of the metal setting so rapidly. It *destroyed the homogeneity* of the metal.

Each addition of aluminium caused the whole to become more crystalline whether in the cast, annealed, or rolled state.

In this series the best all round results are reached with Nos. 3, 4, and 5, after that the metal gradually begins to fall off in its good qualities.

GENERAL CONCLUSIONS.

1. That the addition of aluminium slightly increases the breaking strain, and proportionately the elastic limit in rolled steel and cast, according to the quantity added, up to not more than 1 per cent., when further additions do no more good.
2. That it also slightly improves the extension in rolled steel up to an addition of .5 per cent., but after that each addition reduces extensibility.
3. That the results are not so much better as to make it desirable to add the metal to steel intended for rolling, &c.
4. That in view of its rendering the steel more crystalline, anything beyond small additions would be undesirable for castings; for the same reason, it would not be desirable to use it at all for large castings, having considerable thicknesses of metal.
5. That it would be useful, because of a greater fluidity of the steel, where castings with comparatively thin metal are to be run. The quicker cooling here would prevent an undue development of crystalline structure, and practice and experience will ensure satisfactory tests.
6. Contraction cracks are more liable to occur with this steel, unless temperature of castings be kept low.

OBITUARY.

✓**DANIEL ADAMSON**, Past-President of the Iron and Steel Institute, was born at Shildon, near Darlington, in 1818, and died at his residence, The Towers, Didsbury, near Manchester, on the 13th January 1890. He was apprenticed under the late Timothy Hackworth at the Shildon works of the Stockton and Darlington Railway Company, where he remained until 1841. This pupilage gave Mr. Adamson exceptional chances and experience. At that time the Shildon works, next to the works of Messrs. Stephenson, at Newcastle-on-Tyne, were regarded as the nursery of the locomotive engine, and Timothy Hackworth, whose connection with some of the most notable improvements in the locomotive is very well known, was justly regarded as one of the most competent railway authorities of his time. After leaving the "shops," Mr. Adamson acted for a time as managing draughtsman under the late Mr. William Bouch, and a little later he acted as superintending engineer of the Stockton and Darlington Works. From 1847 till 1849 he was the general manager of the Shildon Engine Works, an appointment which was conferred on him at the comparatively early age of twenty-nine. No higher compliment could have been paid to his aptitude and capacity by those who had the best reason to know the extent and the value of both.

Mr. Adamson, however, was not content to remain long in a subordinate capacity, or in a sphere where there appeared to be set limits to his acquisition of knowledge and experience. In 1850, accordingly, he resigned his appointment at Shildon to become the general manager of the Heaton Foundry, near Manchester. In this capacity he turned out a considerable amount of useful work, including the construction of a cotton-mill at Stockport, of which he prepared the plans in 1850-51. In the latter year he left Heaton to commence business on his own account at Newton Wood. At the Newton Moor Ironworks, near Manchester, he carried on an extensive business for twenty-one years as engineer, ironfounder, boiler-maker, &c., until the works became too small. In 1872 he erected new and more commodious engineering

works at Hyde Junction, Dukinfield, near Manchester. These were afterwards enlarged, and they exemplified in the fullest degree all the modern essentials of a great engineering establishment. The works cover nearly four acres, and usually employ over 600 men, whose wages are stated to amount to about £40,000 per annum.

Mr. Adamson distinguished himself as the patentee of a series of inventions, extending over a period of thirty years. In 1852 he patented the flange seam for high-pressure boiler flues, which is used throughout the trade by the best boiler-makers, and is known as the "Adamson flange seam." He also patented improvements in the super-heating of steam between the cylinders of compound engines, &c. In 1857 and 1858 he applied steel to the construction of locomotive boilers, and subsequently made over 2800 steel boilers for working at pressures varying from 50 lbs. to 250 lbs. per square inch. In 1858 he also patented hydraulic lifting-jacks, and the application of hydraulic power for riveting metallic structures. During 1861 and 1862 he built a triple-cylinder compound engine under a patent of his own, and in 1873 quadruple-action compound engines were made by him, under a further patent for reducing and economising steam. In 1862 he patented and commenced the making of steam boilers by drilling the rivet-holes through the two plates together after the plates are put into position. This method of drilling holes is now generally applied in the practice of boiler manufacture.

In 1863 and 1864 Mr. Adamson erected the Yorkshire Steelworks at Penistone, and became part owner of the first works built in this country to depend entirely on the making of steel on a large scale solely by Bessemer plant. In 1863 he set himself to try to improve what he regarded as defects in steel-making plant. He patented improvements in converters for Bessemer steel, and in 1863 and 1864 he introduced improved blast engines for blowing Bessemer vessels with pistons with metallic surfaces.

Up to the time of his death, Mr. Adamson manufactured all classes of heavy machinery as well as general millwright work and hydraulic machinery, and was the sole manufacturer of several American specialties, notably of engines fitted with the Wheelock automatic expansion gear, which obtained a high prize in all competitions. The Wheelock engine, exhibited by him at the Inventions Exhibition in 1885, gained the gold medal. Mr. Adamson had in recent years patented other inventions, such as compressing machinery and boiler furnace and testing machinery. Testing machines were fitted up at his

works from 30 to 2000 tons power, for estimating the breaking strength of bridge iron and for other purposes. At the Edinburgh International Exhibition, a gold medal was awarded to his firm for their horizontal engine, which had been used in connection with electric lighting machinery. Among Mr. Adamson's recent inventions may be named a labour-saving arrangement by which it is said that as many as twelve tools can be worked simultaneously on a 60-ton bed. Mr. Adamson also took an interest in the fight between guns and ships, and had recently patented a new breech-loading gun, the principal characteristic of which was a new and effective arrangement of the breech.

Having sold the Penistone works to Messrs. Charles Cammell and Co., of Sheffield, who carried them on until a year or two ago, Mr. Adamson cast his eyes in the direction of another fresh field—that of Lincolnshire, which was just then coming into prominence as an iron-making centre. Here he was one of a company that erected, and have for more than twenty years successfully carried on, the North Lincolnshire Ironworks, Mr. Adamson having for the greater part of that time acted as chairman. A number of other blast furnaces have since then been erected in this district, but those of the North Lincolnshire Company have been all along the largest, and probably no other works in that district have been attended with so high a measure of prosperity. Excepting his own works at Manchester, these were the only works of their kind in which Mr. Adamson took a leading interest, although he has been a shareholder in ironworks in South Wales and Cumberland. It was, however, as a manufacturer of iron and steel boilers that Mr. Adamson chiefly made his mark. He did this in three different ways, each of them notable, viz.:—(1.) By the early adoption of Bessemer and open-hearth steel instead of iron; (2.) by the recognition of the importance of using high-pressure steam generally, and thereby economising fuel; and (3.) by the advocacy of drilling instead of punching rivet holes already referred to.

Dr. Dalton, another Manchester man, ascertained in 1801 that atmospheric air and other gases doubled their volume by increasing their temperature 480 degrees Fahr. This law, which he had mastered at an early stage of his career as a boiler-maker, led Mr. Adamson to consider whether it would be possible to introduce in boiler construction an intermediary appliance which would not only prevent condensation but enable Dalton's law to be taken advantage of. He thereupon introduced a system of quadruple engines, provided with an intermediate receiver and super-heater, with a blow-off pressure of 110 lbs. per square

inch, which at that time, about 1873, was regarded as a perfectly novel and even doubtful departure in engineering. Mr. Adamson's first engine on this principle was fitted up in a Manchester cotton mill with over 48,000 spindles, in which he succeeded in reducing the consumption of fuel to 1.77 lb. per horse-power per hour, working the engine, of course, at a much higher pressure than was then usual or regarded as safe. The compound engine had, of course, been introduced many years previously by Mr. John Elder, of Glasgow, and others, but to Mr. Adamson is due the credit of having foreseen that triple and quadruple expansion would be adopted in course of time, and so far back as 1875, in a paper which he read at Manchester before the Iron and Steel Institute,* he expressed his belief that 150 lbs. steam pressure might be used "with less risk than the present system admits of carrying 50 lbs. per square inch on stationary boilers." He stated at the same time that the manufacturer and user of steam ought to be able—by using multiple engines, with super-heating in the lower range of pressures between the cylinders, and nursing the heat of the steam as it passed on from cylinder to cylinder with every possible care—to reduce his consumption of coal to 1 lb., or at the most 1½ lb., per horse-power per hour. His anticipations have since then been realised.

At one time there was a considerable controversy among engineers as to whether the punching or the drilling of boilers was the proper mode of treatment in providing the rivet holes. Mr. Adamson made up his mind after a long and careful series of experiments, and arrayed himself on the side of those who stood for drilling with great effect. He described punching as a barbarous mode of treatment, which destroyed the fibre of the material, and led to accidents, and in his own works he never would allow any piece of metal to be subjected to treatment of this kind. As a boiler-maker and "manufacturing engineer," as he was accustomed to call himself, Mr. Adamson enjoyed a reputation second to none for the solidity and quality of his work and his extreme care in turning it out satisfactorily. He had every plate subjected at his own works to the most careful tests, both chemical and mechanical. This fact, of course, enabled him to accumulate a great deal of experience as to the qualities of steel and iron which could be obtained in no other way, and the earlier fruits of this experience were communicated to the Iron and Steel Institute in 1878, in a paper read at Paris "On the Mechanical and other

* "On High-pressure Steam generally, and its application to Quadruple Engines."—*Journal*, 1875, p. 360.

Properties of Iron and Mild Steel." This paper was of a very elaborate and thorough character, and formulated certain laws and principles in reference to the qualities and manipulation of steel that have been of much subsequent service to the trade. It was Mr. Adamson's intention to have written another paper, bringing the subject more fully up to date, and he had accumulated a large mass of materials with that end in view, which may yet be published.

The idea of a waterway for ocean-going vessels, affording Manchester access to the sea, had engaged the attention of the inhabitants of Manchester from time to time during the last sixty years—in 1825, 1841, and 1877—but it was not until Mr. Daniel Adamson, who was in full sympathy with the objects of those who had been ventilating the subject in the press, organised a committee, with their assistance, that the movement had its practical inception. Mr. Adamson was so satisfied with the case put before him that he resolved to make the Ship Canal project the main object of his energy. Accordingly, on June 8, 1882, he sent out an invitation to a large number of influential municipal representatives of the most important manufacturing towns of Lancashire, Cheshire, and the West Riding of Yorkshire, and to some of the most influential merchants and manufacturers in these districts, to a meeting to be held on June 27 at his house. The meeting was of a thoroughly representative character, and was attended by a large number of the wealthiest and shrewdest men of Manchester, and the area of which it is the commercial capital. Not only were manufactures and commerce represented by sixty to seventy leading merchants and manufacturers, but the great interest felt in the project was further evidenced by the presence of a number of municipal dignitaries, amongst whom were eleven mayors of the towns most immediately interested. The result of the meeting was the appointment of a Provisional Committee, with Mr. Adamson as chairman, and the commencement of a guarantee fund to cover preliminary expenses. Of two plans, submitted, respectively, by Mr. E. L. Williams and Mr. Hamilton Fulton, the latter, which was "to straighten, deepen, and widen the Irwell and Mersey rivers between Trafford Bridge, Salford, and Liverpool, so as to afford a depth at low-water spring tides of 22 feet," was abandoned, and that of the former engineer was adopted, which was "to construct the navigation, with a series of large locks, capable of passing ocean-going vessels as well as smaller ones, and so as to maintain the water at nearly its present height at the docks at Manchester." The prolonged Parliamentary conflict which ensued

was one of the most arduous and protracted in the annals of private Bill legislation. The inquiries of the Select Committees appointed to investigate into the merits of the project during three sessions of Parliament extended over a period of 175 days. The number of the examinations-in-chief and cross-examinations of witnesses exceeded 1000, and their exhaustive character is illustrated by the fact that no less than 87,936 questions were proposed and answered, making in all 175,872 interrogatories and replies, the daily average of questions put and answered exceeding 1000. The proceedings resulted in the incorporation of the Manchester Ship Canal Company by the Act 48 and 49 Victoria, cap. 188, which received the Royal assent on the 6th August, 1885.

As to the moral qualities and character of Mr. Adamson, we cannot do better, perhaps, than reproduce the following extract from a leading article that appeared in the *Manchester Guardian* on the day following his decease:—

“Mr. Adamson was emphatically a man of action. He was bent upon doing, and he could conceive of no reasons why the thing he wanted done should not be done out of hand at once. In his own career he had been eminently successful. He had carved out his own fortune, and he had done so largely by the force of an indomitable will. In his private enterprises he had nobody but himself to consult. He had relied upon his own judgment, he had formed his own decisions, and it was seldom necessary for him to consult other minds before carrying them into effect. Moreover, he had to do with iron. This was the staple material of his business. How to manage this and fashion it into skilful mechanisms according to model was the task which engrossed his thoughts from boyhood. The material in question, stubborn, unyielding, utterly impracticable as it seems to inexperienced eyes, is malleable by heat and hammer, and can be bent as easily as the fingers of a child. To a man conversant through a long lifetime with operations of this kind, and with nothing else, how easily would the conclusion be wrought into his very nature, that mere force and will directed by one brain and applied by a few attendant hands could accomplish anything. He had a great fund of eloquence, to which the Doric accent of the North added a great charm. His fancy glowed when he discoursed on his professional pursuits, and his wide knowledge furnished him with an abundance of metaphors for illustration which were caught up as they were wanted and dropped the moment they had done their work. He would dwell with something like

pathos upon the rottenness of iron under frequent percussion. You could hammer the very soul out of it, till it became almost like tinder. The Ship Canal scheme was not more unconquerable than iron. It only needed setting about with a will and with plenty of heat and hammering, and everything that was toughest in it would give way. It was in this respect that he had to discover the fallibility of his conclusions. The carrying out of the Ship Canal scheme involved above everything else, as a first and last ingredient, the management of men, with whom mere force, whether of will or of passion, availed nothing. The mechanical genius which reigned easily supreme in the workshop was but ill suited to the atmosphere of a committee, and when one will clashed with twenty, numbers necessarily, and, as a matter of justice, considering that each will had a head behind it, carried the day.

"In this way it happened that Mr. Adamson had to take leave of his colleagues and go into retreat, leaving his nursling, now grown almost to adult stature, in their hands. The critical stage in the enterprise was reached, the financiers had to be consulted, their views considered, and even their nerves treated with some delicate regard. A single blunder at this point would have upset everything, and the scheme would fail, in spite of any amount of popular enthusiasm and any number of Parliamentary Bills. The financial stage of the undertaking called for the services of men skilled in finance and endowed with proper sentiments of deference for those with whom it rested to supply the sinews of war. But nothing can ever deprive Mr. Adamson of the honour of having been the originator of the enterprise, and much more than the originator. He drove it into the popular mind. He welded the two things together so that they became inseparable. The Ship Canal was soon a fixed idea. No scepticism and no argument could displace it. He knew the effect of frequent percussion, and the result corresponded to his experience. The success of the scheme with the people of Manchester and of Lancashire in general was something without precedent. Town after town was captured. The municipal wards were roused and organised, the people shouted and the Councils capitulated. Every victory in Parliament was the occasion for a public demonstration. Oxen were killed and roasted, the church bells were set ringing, and triumphal arches raised. Mr. Adamson was the most popular man in Lancashire. His name became a household word, and it was a word which had some magic in it. At his call thousands of persons, to whom investments had hitherto been a thing unknown, began calculating how many shillings would buy a share in the Ship

Canal, and how by clubbing together they could help to build it. Mr. Adamson has undoubtedly disclosed to us some secrets in the 'natural history of enthusiasm.'"

Mr. Adamson became a member of the Iron and Steel Institute in 1869. Four years later he became a member of Council, and he continued to hold that position until he was made Vice-President in 1885. In 1887, he was elected President of the Institute, in succession to the late Dr. Percy, and on the 9th of May 1888 he was presented with the Bessemer gold medal, as a recognition of the valuable services which he had rendered in the development of the knowledge and use of the properties of Bessemer steel. Mr. Adamson seldom missed a meeting of the Institute during his long connection with it, and while, during the first five or six years of his membership, he was an excellent listener, and hardly ever spoke, he was induced during later years to contribute freely to the discussions the fruits of his long and ripe experience. His colleagues on the Council have suitably acknowledged Mr. Adamson's services to the Institute.

✓ HENRY BLECKLY, chairman of the Pearson & Knowles Coal and Iron Company, Limited, died at his residence, Bellefield, Bowdon, on Friday, January the 24th, at the age of 78. Mr. Bleckly was born at Ipswich, and in his earlier business career was connected with banking interests at Newcastle-on-Tyne and London. In 1856 he became connected with the Dallam Forge, at Warrington, which had then not long been established by Mr. George Wordsell. The Bewsey Works were at this time owned by Rylands Bros., and after Mr. Bleckly became connected with Dallam, both that works and the Bewsey Forge were largely extended until the two establishments were divided only by a narrow boundary line, when they were amalgamated and carried on as one concern. Later on the extensive collieries of Messrs. Pearson & Knowles were incorporated with the ironworks at Warrington, and the Pearson and Knowles Coal and Iron Company (Limited), became the owners of the whole. When Mr. Bleckly went to Warrington in 1856, the Dallam Forge produced about 50 tons of finished iron weekly. Under his guidance, however, the production of the Dallam and Bewsey Forges was developed until a weekly output of 2000 tons of finished iron was attained, and for years past these extensive works have turned out annually about this quantity of finished material.

The late Mr. Henry Bleckly was a man of great ability, and the great business of the Pearson & Knowles Coal and Iron Company (Limited)

remains as a testimony to his remarkable commercial talents. He leaves five sons, all of them engaged in the management of the various departments of the Pearson & Knowles Coal and Iron Company ; but, until a few weeks before his death Mr. Bleckly was himself much at the works, generally watching the progress of business rather than actually directing the affairs of the Company. His advice up to the last was as valuable to the Company as it had been in the earliest days of his connection with the iron trade at Warrington. Thirty years ago, Warrington was hardly to be reckoned among the iron manufacturing centres of England, whereas now its position is one of great importance, owing mainly to the large scale on which the Pearson & Knowles Company's Works are carried on.

Away from business, Mr. Henry Bleckly was a very "well read" man ; indeed, his acquaintance with modern literature was marvellous, when the great inroads which business matters made upon his time are considered. He was a clear and concise writer, and was the author of a number of pamphlets on commercial, literary, and philosophical subjects that have attracted attention.

Mr. Bleckly was Mayor of Warrington a quarter of a century since, and for many years took an active part in the public affairs of the district, discharging the duties of the various offices he filled with conspicuous ability. On the retirement of Lord Derby in 1888, he was elected chairman of the Liverpool County Quarter Sessions, to the duties of which position the last eighteen months of his life were largely devoted. Up to a few weeks before his death, he was much interested in the proceedings of the Commissioners appointed by the Board of Trade to inquire into the new classification and schedules of maximum rates and charges deposited by the principal railway companies, in accordance with the requirements of section 24 of the Railway and Canal Traffic Act of 1888. He wrote voluminously on the subject, and felt strongly that the railway companies had, as he argued, broken faith with the traders by demanding maximum rates in excess of their existing statutory powers. He had prepared a proof with a view to examination before the Commission, as one of the witnesses for the British Iron Trade Association, of the Board of which he was an active member, but his decease deprived the tribunal of the advantage of his valuable testimony. Mr. Bleckly was one of the original members of the Iron and Steel Institute, but did not take much part in its proceedings, the bent of his mind being commercial rather than technical.

✓ ALFRED C. HILL was born at Ebbw Vale on the 17th of October 1835. His father, Mr. Samuel Hill, of whom he was the youngest child, held the position of engineer at the Ebbw Vale Ironworks for about twenty years. In 1836 the family removed to Llanhylleth, a few miles down the valley, and in 1839 to Risca, near Newport. Here they remained for some years, but eventually went to reside at Newport, where Mr. Hill entered on his professional career at Ukside Ironworks. It was during this period that he became acquainted with the late Mr. Thomas James, of Redcar Ironworks. In the year 1854 Mr. James and he became engaged to B. Samuelson, Esq. (now Sir Bernhard), Mr. James as manager, and Mr. Hill as mechanical draughtsman. He afterwards acted as head draughtsman to Messrs. Bolckow & Vaughan, at their Middlesborough works, and upon the accidental death of Mr. Williamson, in October 1856, was appointed engineer. In 1858 he went to Witton Park and erected a blast furnace there, after which he was given the management of the blast furnaces and the rolling mills.

In 1863 he erected the Clay Lane blast furnaces, and managed them when completed, as well as the South Bank furnaces. He also acted as engineer for the Bishop Auckland Ironworks. In 1870 he was engaged by the Lackenby Iron Company to build the Lackenby furnaces. These he managed till 1876, when he again undertook the management of the Clay Lane and South Bank furnaces. The South Bank works being eventually sold, he continued to manage the Clay Lane furnaces up to the time of his death.

In addition to his regular employment, he acted as constant or occasional consulting engineer to the following works:—Messrs. The Outward Iron Company, near Manchester; Messrs. The Yniscedwyn Iron Company, Yniscedwyn; Messrs. The South Cleveland Iron Company, Glaisdale; Messrs. The West Marsh Iron Company, Middlesborough; Messrs. Thomas Allen & Sons, Stockton. He was also consulting engineer at the following mines and collieries:—Kilton, Craghall, Liverton, West Hunwick, and Pelaw Main. He was occasionally consulted by the late Mr. Edward Williams and Messrs. Palmers' Ship-building and Iron Company, Limited, Jarrow-on-Tyne. He was a member of the Institute of Mechanical Engineers, a member of the Iron and Steel Institute, and a Past President of the Cleveland Institution of Engineers.

✓ JOHN HUGHES, of the town of Hughesovska, in Southern Russia, 1890.—i.

called after his name, was born at Merthyr, in South Wales, in 1814, and died suddenly at St. Petersburg, in July 1889. Mr. Hughes was trained in his native Principality as an ironworker, and became a competent mechanical engineer as well. On leaving his own neighbourhood, he was employed in different capacities at engineering works in London and elsewhere. While residing in the Metropolis, his attention was called to the great facilities offered by the south of Russia for the prosecution of the iron manufacture, and he took a leading part in the establishment of a company, known as the New Russia Iron Company, of which he became the managing director, promoted with the view of acquiring mineral properties, and erecting iron and steel works, in the locality that bears his name. The works have been carried on by Mr. Hughes for nearly twenty years with conspicuous success. Some of the best-known men connected with the engineering profession in England are among the shareholders. The Hughesovska Company raise their own coal and iron, make their own pig in three modern furnaces, and produce bar iron and Siemens steel. When Mr. Hughes selected the site where his works now stand, there were only a few miserable huts in the neighbourhood, so that great difficulties on the score of efficient labour and domiciliary accommodation had to be met. Mr. Hughes, however, overcame these with his invariable energy, and now the works support a population of nearly 10,000 souls. Mr. Hughes frequently made visits to Europe, and kept himself well *au courant* with the proceedings of the Iron and Steel Institute, of which he had been a member since 1878, as well as those of other bodies. He was well known to, and a *persona grata* with, some of the more prominent Court officials, including the Ministers of Commerce and of Ways and Communications at St. Petersburg; and it is much to his credit that in a country, where there is an instinctive dislike of foreigners, and where he had a most difficult part to play, he so comported himself as to earn the esteem of those who knew him best, at the same time that he did well for his company, which was mainly established with English capital.

JAMES STEWART, tube manufacturer, of Coatbridge and Glasgow, who died in January 1890, was one of the heads of a well-known business that has been largely extended during recent years. The business in question was commenced in a very modest way in 1861, by Mr. Andrew Stewart, in St. Enoch's Wynd, Glasgow. For a time, practically the only work undertaken was the production of gas tubes,

but as a demand for boiler tubes came forward, the works were removed from St. Enoch's Wynd, where they could not, owing to their cramped situation, be further extended, to Coatbridge, some ten miles from that city, where a new departure on a large scale was undertaken. Commencing with a site of four acres, the works have, since 1871, been more than trebled in extent, until they are now among the largest of their kind in the United Kingdom. More recently, an adjunct has been opened up in the Firhill Road, Glasgow, for the manufacture of cast-iron pipes, of which the firm is now producing large quantities. Deceased, who was in his fifty-second year, left a widow and five children. He became a member of the Iron and Steel Institute in 1873, and took an active part in the reception of the Institute at its Glasgow meeting in 1884.

✓ WILLIAM RICHARD JONES, general manager of the Edgar-Thomson Steel Works, Pittsburg, was born in Luzerne County, Pa., on the 23rd February 1839, and died in Pittsburg on the 28th September 1889. He was the eldest son of the Rev. John G. Jones, who emigrated from South Wales in 1832. At the age of ten years he was apprenticed to the Crane Iron Company at Catasauqua, having been put to work at this early age in consequence of his father's failing health. At the works of the Crane Iron Company he went first through the foundry department and afterwards through the machinery shops, and he appears to have made himself thoroughly acquainted with both. In 1856 he undertook the duties of working-engineer at an establishment in Philadelphia, and in the following year, having apparently developed a somewhat roving disposition, he became lumber-man, raftsmen, and farm hand, in Clearfield County. Two years later he entered the service of the Cambria Iron Company at Johnstown, where, however, he only remained three months. Thereafter he proceeded to Chattanooga, in Tennessee, and he appears to have been getting on there very well when, on the breaking out of the war, he was summoned to his own district. In 1862 Jones enlisted in a company of the 133rd Pennsylvania Volunteers. At the crossing of the Rajudan he was somewhat badly injured, but although suffering greatly, he refused to leave the ranks. At the close of the campaign he re-entered the service of the Cambria Iron Company, and while acting in that capacity he organised the F Company of the 194th Pennsylvania Volunteers, of which body he was appointed captain. In 1864 he was assigned to the provost-guard in Baltimore, where he served with credit; and in

1865 once more he entered the service of the Cambria Iron Company, as assistant to the general engineer. In that capacity he took part in the construction of the Cambria Company's Bessemer Steel Works. On the completion of the new Cambria Company's plant he became master mechanic, and he subsequently entered the service of Messrs. Carnegie, Phipps & Co. as general superintendent of the Edgar-Thomson Steel Company.

Under the management of Captain Jones, the Edgar-Thomson Works have become the most productive of their kind in the world. The total output of pig iron at these works during the current year will not be less than 800,000 tons; while the production of steel of all kinds will exceed half-a-million tons. Captain Jones took an active part, not only in superintending the actual progress of manufacturing operations, but also in building a number of the furnaces and other plant that have made the Edgar-Thomson Works what they are to-day. Seven of the principal blast-furnaces owned by Messrs. Carnegie Brothers were constructed under his direction, and it is acknowledged on all hands that these furnaces have been remarkable even in the annals of American blast-furnace practice for the enormous yields that they have produced, some of them having turned out more than 2400 gross tons per week for a lengthened period.

Captain Jones's improvements and inventions have had much to do with making these furnaces, which are, however, ably managed by Mr. Gayley, the first in the world. His inventions are as numerous as they are useful. The first were "a device for operating ladles in Bessemer processes" and "improvements in hose couplings," patented December 12, 1876. In the same month he also patented fastenings for Bessemer converters. His other more important patents were—washes for ingot moulds, 1876; hot-beds for bending rails, 1877; apparatus for compressing ingots while casting ingot-moulds, 1878; cooling roll-journals and shafts, 1881; feeding appliance for rolling-mills, and art of making railroad bars, 1886; appliance for rolls, apparatus for removing and setting rolls, housing caps for rolls, roll-housings, 1888; and apparatus for removing ingots from moulds, 1889. His latest and, as some think, his greatest invention, is a method for mixing the iron taken from blast-furnaces and charged into two receiving-tanks previous to being poured into a converter. Letters patent on this invention have been allowed, but had not been issued at the time of his death.

Captain Jones became a member of the Iron and Steel Institute in 1881, and in the same year he furnished to the Institute two papers

on the manufacture of Bessemer steel and steel rails in the United States. In these papers he described the methods of working the Bessemer plant at the Edgar-Thomson Works, and gave an explanation of the reasons that enabled the American works to turn out such large yields as they did. Captain Jones combated the impression that fast running leads to the production of inferior steel, contending for the converse proposition that it was difficult to obtain great speed in working while bad steel was being produced.

Captain Jones met his death from an accident which occurred at the Edgar-Thomson Works while he was fulfilling his duties as superintendent of that establishment, and it has been a source of great regret to his numerous friends, both in the United States and in Europe, that he should thus have been called away in the prime of life. His employers have shown their sense of the value of his services by a series of resolutions which they adopted on the 3rd October 1889, to the following effect:—

“Resolved, That as this firm, in all its history, has never been called upon to record a loss so tragic as that which has deprived it of its great manager, Captain William Richard Jones, so neither has it ever lost an officer whose services were more valuable, or to whom it was more deeply indebted for the success which has attended its operations.

“Resolved, That invaluable as the services of Captain Jones have been, not only to us, but to the steel manufacture in general, the remembrance of these fade away in the keen pangs of grief awakened in us by recollections of our friend, the man.

“Resolved, That the history of the steel manufacture will record his name with those whose joint labours have brought the art to its present state of perfection, and in the list of men who have risen from the ranks through the possession of indisputable genius to commanding positions as organisers and managers of masses of men in the industrial armies of this age, the highest rank must be accorded to Captain Jones.

“Resolved, That to us, his employers and friends, who knew him intimately through many years of almost daily intercourse, there is still left in our grief, though he has gone, the precious privilege of meditating upon a combination of manly qualities, which constitute the real man, and which, united in him, gave forth that indefinable but rarest quality, character: a brave, just, honest, transparent soul; a staunch, loyal-hearted, generous friend was he, whose absence from us and from our counsels we to-day so deeply mourn.

“Resolved, That his life should have been sacrificed in our service

must ever hereafter tinge our thoughts of the Edgar-Thomson Steel Works with feelings of profound regret, and yet we would not forget that the Commander fell at the head of his men, at the post of duty, amid the roar of the vast establishment, which was his work, and which is his monument. A heroic end was his, worthy of the soldier he was; for Captain Jones fell upon the field which he had conquered."

✓ WILLIAM STROUDLEY was born on the 6th March, 1833, at Sandford in Oxfordshire, and died in Paris on the 20th December, 1889. In 1847 he became apprentice to Mr. John Inshaw, an engineer of Birmingham. In 1840 he was engaged in working the engine of a twin-screw passenger boat which was started in that year on the canal between Birmingham and Wolverhampton by his employer. In 1848 he was sent to work an engine at the Vulcan Foundry, Birmingham, and in 1849 he was employed in fitting up the engines and boilers of eight steamboats which Mr. Inshaw had undertaken to provide, on the twin-screw principle, for the Grand Canal Company of Ireland. Afterwards, young Stroudley went to Dublin to assist in erecting these engines, and he was engaged on this and similar work until 1851, when he entered the service of Mr. Edwards, of Islington Foundry, Birmingham. For the next year or two Stroudley was engaged in various branches of practical engineering, including the erection of a large condensing engine for a corn-mill, and of a pair of compound engines for a paper-mill. In May 1853, having left his original employer, Stroudley was engaged at the Swindon Locomotive Works, when that establishment was under the superintendence of the late Sir Daniel Gooch, afterwards Chairman of the Great Western Railway Company. At Swindon, he had a varied experience in locomotive engineering, his first employment being mainly that of fitting up valve and slide motions for some new goods engines. In the following year he entered the service of the Great Western Railway Company, and was employed by them at their Peterborough shops as a running-shed fitter. In the same year he was working-foreman, and in that capacity had charge of the ordinary repairs of the passenger engines. Three years later he was asked by Mr. Sacré, then locomotive superintendent of the Great Northern line, to take charge, for Lord Willoughby D'Eresby, of a short line which had been unsuccessfully managed up to that time. In the following year he undertook the charge of some engines and machinery at the Helpstone Paper Mills, and in 1859 he returned to Peterborough, where he again was entrusted with the

charge of repairs to the passenger engines. In 1861 Mr. Stroudley became manager of the Cowlairs Works of the Edinburgh and Glasgow Railway, now a part of the North British system, where he not only had charge of the repair and construction of locomotive engines, carriages, and waggons, but was also entrusted with the charge of the drawing-office. While employed at Cowlairs, Mr. Stroudley designed and built a small engine for a steam yacht, and is said to have succeeded in producing the fastest and lightest boat on the Clyde, the builder having been Mr. William Denny of Dumbarton. In 1865 he was appointed locomotive superintendent to the Highland Railway at Inverness, and in January 1870 he was appointed to the position of locomotive and carriage superintendent of the London, Brighton, and South Coast Railway. In this capacity, in addition to the locomotive and carriage departments of the company at Brighton, he had charge of the engines and machinery of the steamers working in the service of the company between Newhaven and Dieppe. During the twenty years that Mr. Stroudley was filling this position he witnessed very considerable extensions of the operations of the company, which, at the time of his death, had a system of 435 miles, and carried in 1888 thirty-nine millions of passengers, besides twenty thousand season ticket holders, its total gross income having been £2,320,000.

Mr. Stroudley, during the whole of his career as a mechanical engineer, devoted much time and attention to the subject of economy of fuel in both locomotive and stationary engines. When he accepted the charge of the steam engines and machinery at the Helpstone Paper Mills he introduced improvements of different kinds, which made a considerable reduction in the consumption of coal. He was successful in securing a lighter coal bill in most of the work that he undertook, and for a number of years he made it a regular practice to obtain from all the leading companies in the United Kingdom particulars of their coal bills, in order that he might compare the average consumption with that of the engines employed by his own line. This information was published by Mr. Stroudley for his own use and that of his Directors in the form of a tabulated statement, which showed that the consumption of coal on the passenger locomotive constructed and worked by him varied from 15 to 26 lbs. per train mile, with an average load of vehicles varying from 7 to 25 tons. In the case of what was described as a B-Gladstone passenger engine with an average vehicular load of 25 tons, and an average running speed of $43\frac{1}{4}$ miles per hour, the consumption of coal was only $26\frac{1}{2}$ lbs. per train mile.

While in the case of a D-tank passenger engine with an average vehicular load of $13\frac{1}{2}$ tons, and an average running speed of $26\frac{1}{4}$ miles per hour, the consumption of coal was $17\frac{1}{2}$ lbs. per train mile. Results like these obtained for Mr. Stroudley the reputation of working engines at almost, if not quite, the lowest fuel consumption known in this country. And this, of course, was a matter of supreme importance to the Brighton Company, which has to pay considerably more for its fuel supplies than the companies north of London.

Mr. Stroudley was recognised by the members of his profession generally as being in the front rank of mechanical engineers especially in reference to the construction and working of locomotives. He was thorough in everything that he did, and his practice at Brighton was often quoted as being amongst the best of its kind. He was always ready to acknowledge and adopt mechanical improvements, whether originated by himself or by others, and in proof of this fact it may be stated that, at an early stage, he adopted the Westinghouse brake, with modifications, on the Brighton system; while at a comparatively early stage he introduced the compound system on the steamships belonging to the Brighton Company. He also introduced at the Brighton works the system of the interchangeability of parts, in which he was a firm believer—his principle being that many parts of engines of different classes should be made, as far as possible, interchangeable. For passenger engines he made use of exceptionally large leading-wheels, whereby he was enabled to utilise the weights of the cylinders and motion for adhesion, and to avoid the use of cast-iron foot-plates.

Mr. Stroudley was a member of the Institution of Civil Engineers, where, in 1885, he read an important paper on the "working of locomotives" for which he was awarded the Telford medal and premium. He was also a member of the Institution of Mechanical Engineers, and of the Iron and Steel Institute, having joined the latter society in 1888. At the Paris Exhibition of 1878, he was awarded a medal for one of his engines named the "Brighton," and at the Exhibition of 1889 he was awarded a gold medal for another engine called the "Edward Blount," which is said to have attracted much notice both from its design and its excellent workmanship.

WILLIAM FREDERICK DENNIS was born at Hythe, in Kent, on 24th December 1844. After being educated at New Kingswood School, near Bath, he was articled to Messrs. Lloyds, Fosters, & Co., of Wednesbury, where he spent six years, passing through the various

shops and departments. On leaving Wednesbury he was employed on the erection of Willesden Junction railway station. He afterwards obtained employment with Messrs. R. & C. Goldthorpe, card-wire manufacturers, of Cleckheaton. In 1869 he went to London and started an agency in the city. He was afterwards joined in partnership by his brother, Mr. Arthur Dennis, and founded the firm of Messrs. W. F. Dennis & Co. The deceased appears to have been one of the first to foresee the position which Germany was likely to attain as a manufacturing country, and even when German productions were comparatively unknown in England, he paid numerous visits to the manufacturing centres on the Continent, and carried out large contracts with most successful results. He acted as agent for one of the largest iron manufacturing firms in Germany—that of Messrs. Felten & Guillaume of Cologne—and did a great deal to have the wire industry of that country further developed. As an engineer he invented the wire-netting machine known by his name, by means of which wire-netting is manufactured on a novel principle, direct from bobbins of hard bright steel wire, without the use of spools. He was also the inventor of a tubular telegraph pole, which is a combination of wrought and cast iron, and is so constructed that it can be erected with great facility. He died at Eastbourne of heart disease on 10th December 1889, in the forty-fifth year of his age. He became a member of the Iron and Steel Institute in 1880.

TO ILLUSTRATE MESSRS. HEAD AND POUFF'S PAPER
ON "A NEW FORM OF SIEMENS FURNACE."

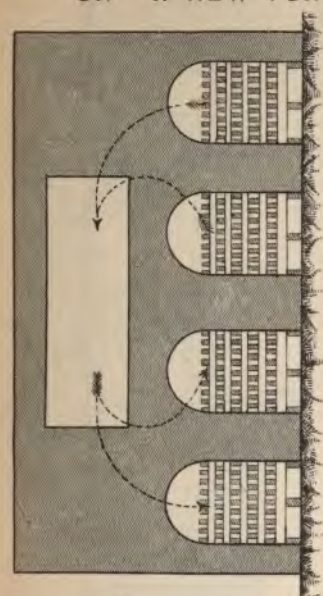


Fig. 2.

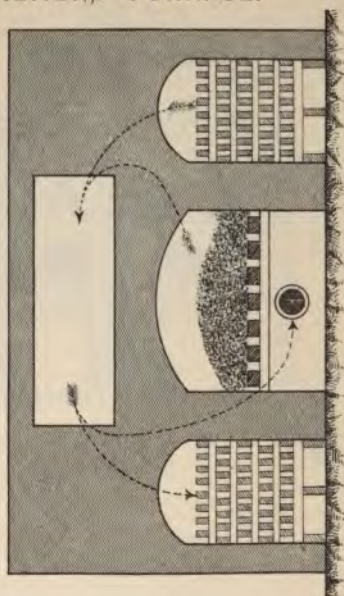


Fig. 3.

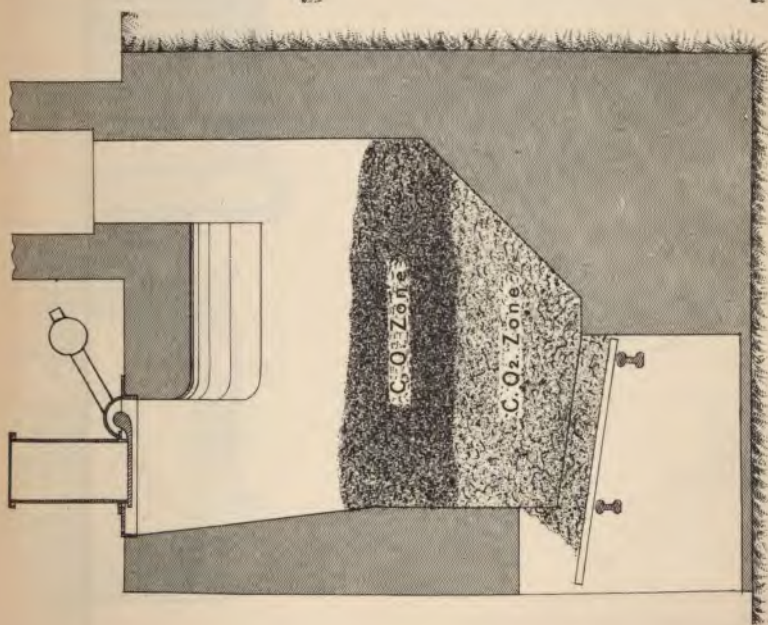
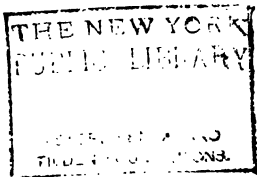


Fig. 1.



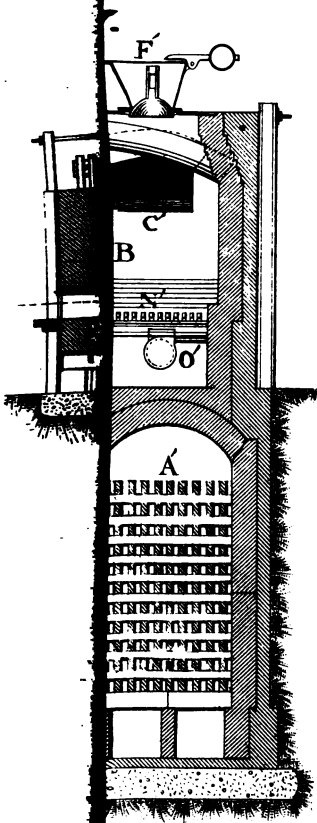


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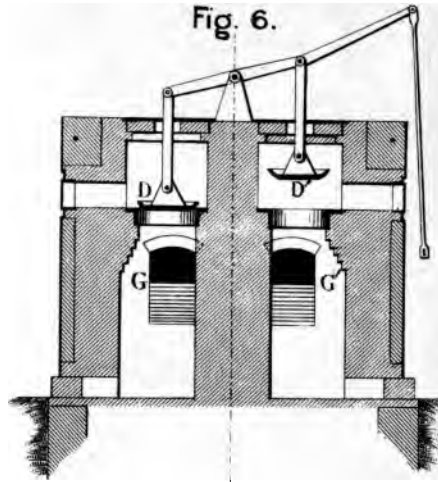
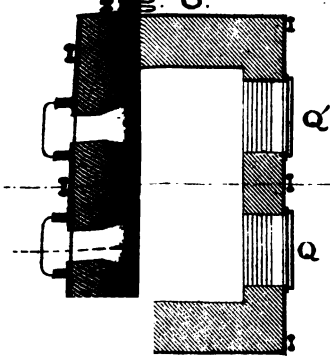
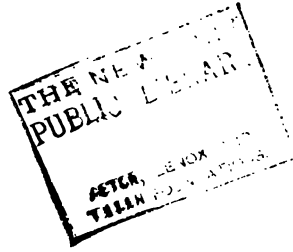


Fig. 6.



CRITICAL POIN

3

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ASTOR LENOX AND
TILDEN FOUNDATIONS

Temperatures

Soft Spot

THE NEW
PUBLIC
ACT OF 1934
F. L. J. S.

TO ILLUSTRATE MESSRS. HEAD AND POUFF'S PAPER
ON "A NEW FORM OF SIEMENS FURNACE."

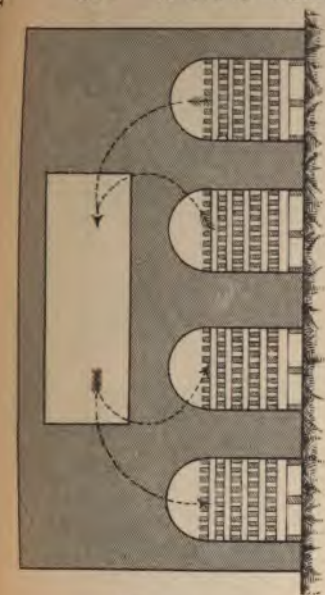


Fig. 2.

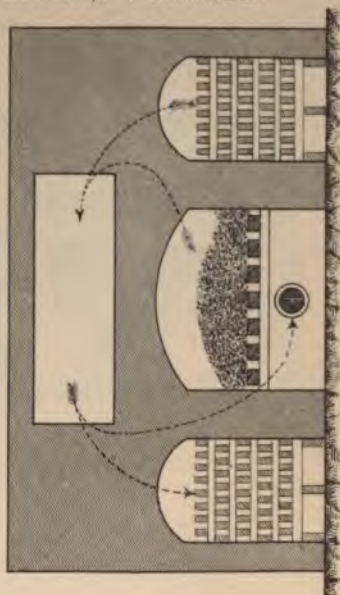


Fig. 3.

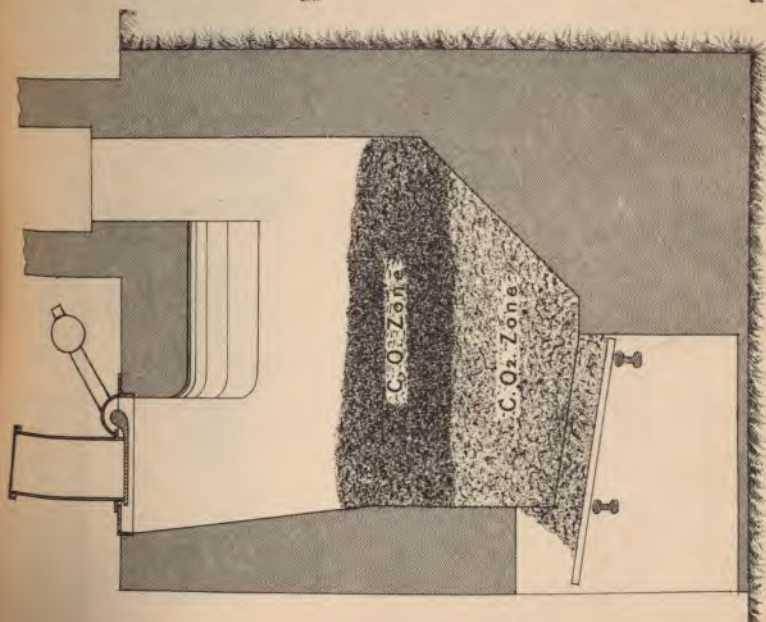
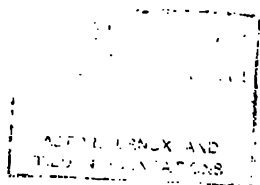
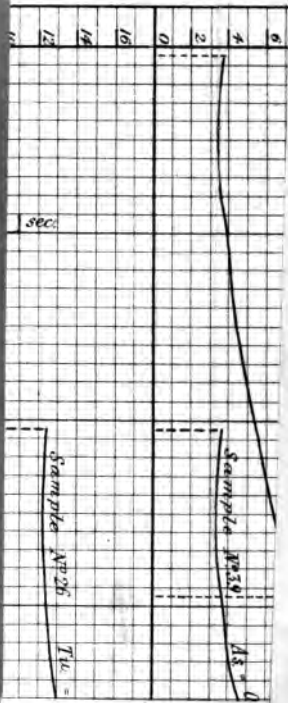


Fig. 1.



E CRITICAL P

5



Time per Square Inch and Degrees on Scale

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ASTOR LENOX AND
TILDEN FOUNDATIONS

TENSILE STRENGTH, AND MAGNETIC CAPACITY OF THE UNSTRAINED BARS

Fig. 1.
HARDENED IN WATER.

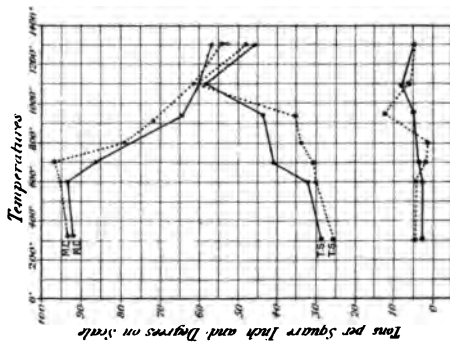


Fig. 2.
HARDENED IN OIL.

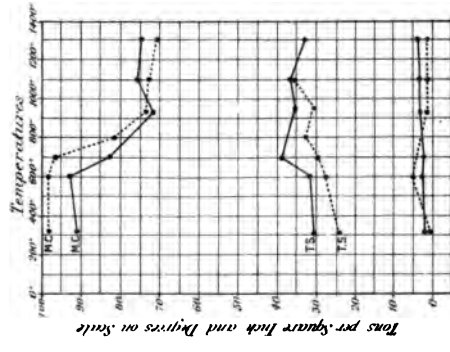
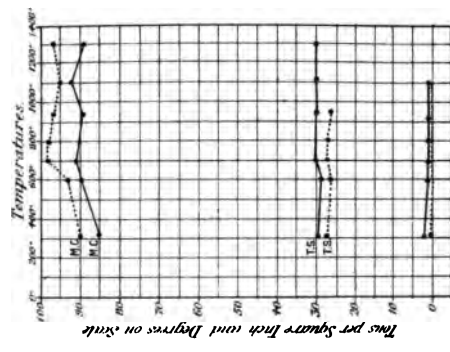


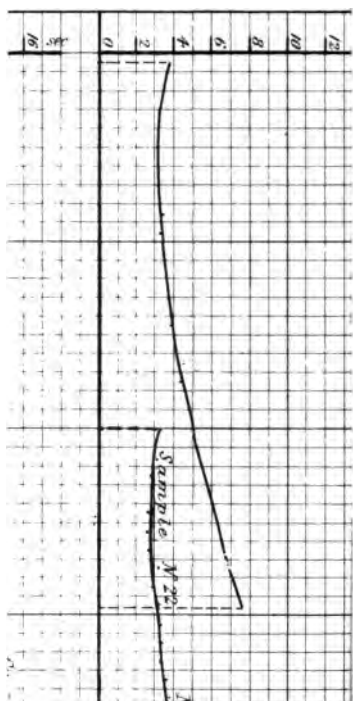
Fig. 3.
ANNEALED.



NOTE: - Basic Bessemer Steel ———, Open-hearth Steel



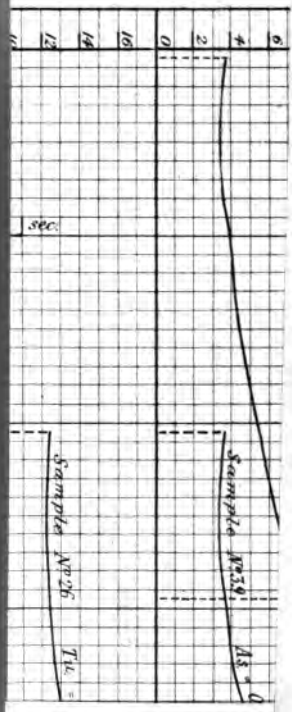
CRITICAL POINT



These data are from the Test Report on Sample No. 201.

E CRITICAL P

5



L

Specimen Name and Number on Side

el Institute

1

TO ILLUSTRATE DR. BALL'S PAPER ON THE CHANGES IN IRON PLATE VIII.
PRODUCED BY THERMAL TREATMENT."

MAGNETIC CAPACITY OF THE SAME BARS STRAINED ALMOST TO THE BREAKING POINT.

Fig. VII.
HARDENED IN WATER

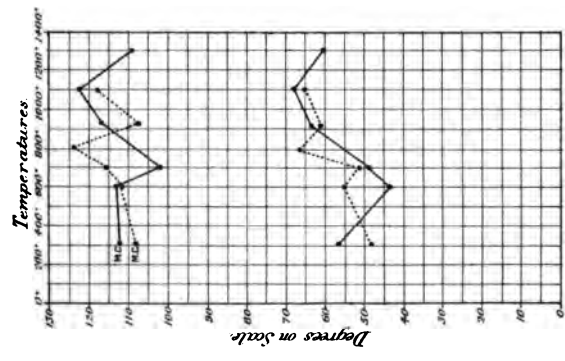


Fig. VIII.
HARDENED IN OIL.

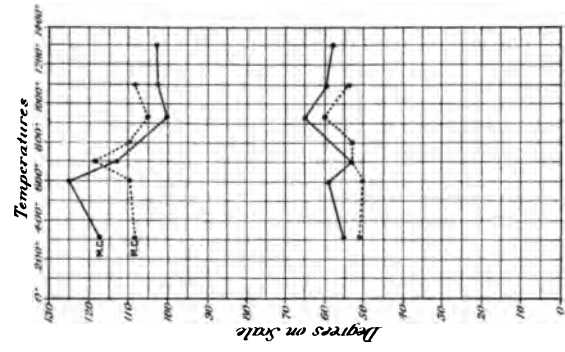
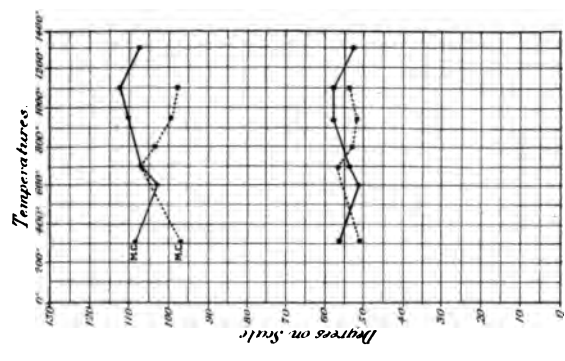
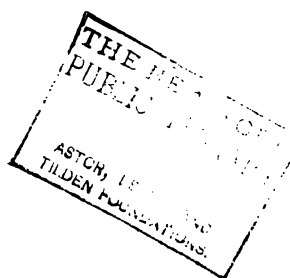


Fig. IX.
ANNEALED.



NOTE:- Basic Bessemer Steel —————; Open hearth Steel - - - - -



TO ILLUSTRATE A. ROLLET'S PAPER ON HIS PROCESS FOR
 PRODUCING A PURE CARBIDE OF IRON.

Fig. 1. Section through XX



Fig. 2.

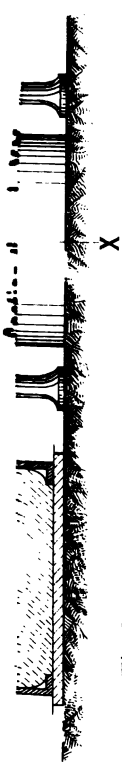
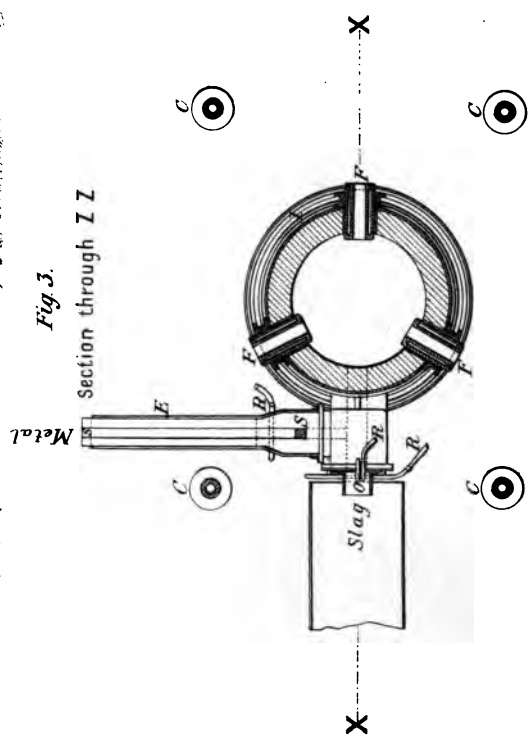
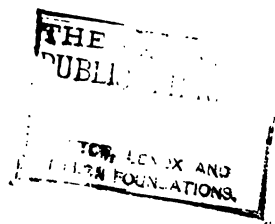


Fig. 3.





NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN

IRON AND STEEL INDUSTRIES.

I.—1890.

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ABSTRACTORS.

EDWIN J. BALL, PH.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES.

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I.—OCCURRENCE AND COMPOSITION.

Antrim Iron Ore.—The deposits of iron ore at Antrim, Ireland, are described by Professor E. Hull.* The ore is found in the strata between the two basaltic sheets which overlie the Cretaceous and older formations. It occurs associated with decomposed volcanic ashes, bole, lithomarge, and bauxite. The iron ore occurs as a band varying from 12 to 36 inches in thickness, of which the upper part is richest. It consists of pisolitic spherules of hæmatite cemented together. The mines are worked by adits driven in the hills at a considerable elevation above sea-level. Mr. Symes has estimated that the ore covers about 167 square miles, and that of the 232,000,000 tons which exist, about 185,000,000 tons may be worked. The maximum output of 231,132 tons was attained in 1880, but in 1888 the production fell to 129,235 tons. The ores are suited for the Bessemer process, as they are remarkably free from sulphur and phosphorus. The following are typical analyses:—

	Kilwaghter.	Tully.	Redbay.†	Glenariff.
Ferric oxide	45·0	45·50	59·40	62·43
Ferrous oxide . . . . .	...	...	...	4·75
Manganese oxide	trace	trace	trace	0·28
Titanic anhydride . . . . .	...	2·00	...	...
Alumina	} 36·44 }	35·00	28·00	10·19
Silica		4·00	10·40	8·40
Magnesia	2·44	...	...	0·59
Lime	0·56	0·35	10·40	2·80
Water	18·00	12·65	8·40	10·36

* *Iron and Coal Trades Review*, vol. xl. p. 35.

† There is evidently a misprint in this analysis, as the total of the numbers given is 116·60.

The Swedish Iron Ore Districts.—A. Vosmaer * describes the Gellivara, Kirunavara, and Luosavara iron ore districts, together with the railway which has been constructed from Luleå to Ofoten with a view to open up these ore deposits. Assays of the ore worked show from 60 to 70 per cent. of iron, the percentage of phosphorus—occurring as apatite—varying from less than 0·05 per cent. upwards. The percentage of sulphur, though usually low, is also very variable. Only relatively very small quantities of ore comparatively free from phosphorus and sulphur exist in these deposits. Of the 50,000 tons shipped from the Gellivara mines in 1888, less than 3000 tons were of first rate quality. The ore is almost free from manganese, and the percentage of phosphorus is so extremely variable, that it cannot be relied on as a definite source of ore either for the acid or the basic steel processes. Its chief value lies in its use as an addition to other ore charges, the percentage of sulphur being, as a rule, extremely low. The author makes a number of suggestions for the modification of the system of mining adopted at the present time.

With reference to the ore of the Kirunavara mines, the author points out that whilst some of the specimens he collected showed 72 per cent. of iron, and only 0·03 per cent. of phosphorus, others showed from 62 to 69 of iron and as much as 2 to 3 of phosphorus. Still, the ore appears to vary according to its position in the deposit; thus the ore near the hill-summits is usually much more impure than the deposits situated lower down. The ore is extremely fine-grained and very brittle.

The author writes much more favourably of the Luosavara deposits. Here the average of eight assays of the ore showed :—

Iron.	Phosphorus.	Sulphur.
70·15	0·03	0·06.

Although comparatively free from both phosphorus and sulphur, the ore contains variable quantities of titanium, sometimes as much as 1 per cent.

The author strongly urges the desirability of putting down bore-holes, both to prove the deposits themselves, and also to ascertain whether the quality of the ore changes with the depth. Without such tests it is quite useless to make such calculations as have been made with reference to the enormous quantities of ore that these deposits must contain. The question as to whether the railway, and the ore deposits

* *Stahl und Eisen*, vol. x. pp. 185-189, 299, 306, with map and illustrations.

themselves, will pay is considered at some length, with a result which is on the whole unfavourable.

The Gellivara Ores.—The iron ores from Gellivara,* in North Sweden, are very rich, and contain 60 to 70 per cent. of iron. In one of the deposits the proportion does not exceed 40 per cent. As a rule, these ores may be smelted alone; but with 5 to 10 per cent. of limestone added, they give a better slag and a greater out-turn. All assays indicate the presence of titanium, which necessitates a high consumption of carbon. The lowest proportion of phosphorus found amounted to 0·011 per cent., whilst others gave as much as 0·374 per cent. On an average, the ore contains 0·04 to 0·05 per cent. of phosphorus, so that under the most favourable conditions pig iron is obtained containing 0·06 to 0·10 per cent. of phosphorus, the consumption of fuel being considerable. The largest of the deposits, however, contain much more phosphorus, as much as 0·5 to 1·5 per cent., and the iron obtained is therefore best adapted for the basic Bessemer process. The percentage of titanium in the ores appears to be derived from the titanite in the containing rock. Thus the Gellivara ores do not yield charcoal pig iron of average Swedish character with 0·05 per cent. of phosphorus. They are more suited for coke blast furnaces, and would yield pig iron with 1 to 2 per cent. of phosphorus.

The more northern deposits of Luosavara and Kirunavara are more easily accessible, richer, and contain more ore at the surface. The Gellivara apatite deposits have greater importance for the future than the iron ores.

The Oolitic Iron Ores of Lorraine.—According to Wandesleben,† the thickness of the Lorraine ore beds varies from 1 to 10 yards. The beds are separated by layers of sandstone, limestone, or marl. The ores yield 28 to 40 per cent. of iron and 1 to 2 per cent. of phosphorus. The average proportion of iron is 33 to 38 per cent. In 1888 Lorraine produced 2,800,000 tons of iron ore, and the whole of the minette district yielded 8,000,000 tons, which supplied some hundred large blast furnaces with a total output of 2,500,000 tons of pig iron, an amount which formed 40 per cent. of the total production of Germany, France, and Luxemburg. The haulage is effected by horses, endless chains, and locomotives. The average production per miner in Lorraine in 1888

* *Wärmländska Annaler ; Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 18.

† *Metzer Zeitung*, through *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 81.

was 884 tons. The cost of production of the ore amounted to 1s. 2½d. to 2s. 3½d. per ton, and the selling price was 1s. 9½d. to 3s. 7d., according to the percentage of iron. The ores are smelted in Lorraine in nineteen blast furnaces.

Iron Ore in the Palatinate.—In the vicinity of Sulzbach, in the Upper Palatinate, a thick bed of manganiferous iron ore has been discovered. It has a thickness of 40 to 60 yards, and extends for two miles. It is intended to sink a deep shaft, and to erect a fourth blast furnace at Rosenberg.*

Iron Industry in Central Russia.—According to P. Träsenster,† the iron industry in Central Russia depends on the ore supply from Krivoi-Rog, or more exactly Saxagan, and on the coal supply from the Donetz basin, 300 miles distant. The ore basin of Saxagan is composed of crystalline schists and clay slates alternating with quartzite, and resting on the surrounding granite. The mineral occurs in a series of lenticular masses in a bed of quartzite, and consists chiefly of specular iron ore, passing into magnetite or red hæmatite. The deposits are generally covered by about twenty yards of earth, and are from twenty to thirty yards above water-level, so that they are advantageously worked in open quarries. There are five or six principal deposits along the river Saxagan, in a distance of seven to nine miles. The ore contains about 65 per cent. of iron, and is free from sulphur and phosphorus. The Donetz basin is the largest coal-bearing area in Europe, and covers more than 7700 square miles, besides which the carboniferous strata extend far under the surrounding secondary and tertiary rocks. Fifty seams have been found with a mean thickness of about 2½ feet, while the thickest bed is 6½ feet. The eastern two-thirds of the basin contains anthracitic coal; the western portion contains coking coal of various qualities. This coal contains a considerable quantity of sulphur, so that it is generally necessary to wash it. The ironworks of Hughesoffska, Ekaterinoslav, and Kamensky are also briefly described.‡

The Titaniferous Iron Ore of Ekersund-Soggendal.—Professor J. H. L. Vogt§ describes the deposit of titaniferous iron ore occur-

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 63.

† *Bulletin de l'Association des Ingénieurs Sortis de l'Ecole de Liège*, 1890, p. 11.

‡ See *Journal of the Iron and Steel Institute*, 1889, No. II. pp. 396–402.

§ *Archiv for Mathematik og Naturvidenskab, Kristiania*. (Excerpt from vols. x. and xi., 101 pages, 8 plates.)

ring in the norite of Ekersund-Soggendal, Norway. The norite covers an area of 460 square miles. Two types of this rock are met with, one consisting almost exclusively of labradorite, and the other of labradorite, hypersthene, and titaniferous iron ore. The deposits of this ore occurring in the norite were formerly regarded as segregations of that rock. Seeing, however, that the deposits possess a distinct vein character, being sharply defined from the containing rock, and enclosing fragments of it, the author regards them as modifications of the coarsely crystalline norite veins that have been observed in the district. At all events, these titaniferous veins are older than the diabase veins, for they traverse these at several points.

The chief of these veins occurs in the St. Olafsfield, near Ekersund. It consists of an ore vein extending for about 3 miles, and 2 to 4, and, in places, as much as 12 yards in thickness. Near this there is a vein of diabase some 30 yards in thickness. The vein material consists of a very pure titaniferous iron ore, mixed with small quantities of labradorite, hypersthene, and iron pyrites. The second important ore vein is one near Soggendal. It is a mile and a half long, and 60 to 70 yards thick. It exhibits a very remarkable banding, in layers of 1 to $2\frac{1}{2}$ yards in width, parallel to the walls of the vein. Some of these bands consist of titaniferous iron ore, with 20 to 30 per cent. of labradorite and hypersthene; others are much richer in silicates. This banded nature is regarded as a fluction texture on a large scale.

Attempts have been made to work this deposit, but the mine is now idle.

Iron Ore Deposits at Ottawa.—Several ore deposits near Ottawa, in Canada, have been examined by Mr. J. Birkinbine,* with the view of investigating the possibilities of iron manufacture there. The present small output of Canadian pig iron has mostly been produced from bog ore and charcoal, both of which are abundant. Coal is found in the eastern provinces, and also in the west of the Dominion, but not within a distance of 700 miles from Ottawa.

There are considerable indications of ore in the province of Quebec, near Hull and Haycock, and a large proportion has been shipped to the United States. Analysis gives the following results:—

* *The Canadian Mining Review*, vol. viii. pp. 129, 130.

	Haycock.		Hull.	
Ferric oxide . . .	88.08	85.45	66.20	} 73.90
Ferrous oxide . . .	6.86	5.24	17.78	
Phosphoric anhydride . .	0.16	0.13	...	...
Phosphorus . . .	...	...	0.015	0.027
Sulphur . . .	0.03	0.07	0.28	0.085
Silica . . .	...	...	11.11	20.27
Titanic anhydride . .	3.17	2.12	none	none
Metallic iron . .	66.98	63.88	60.17	53.51

The Bristol mines, 35 miles from Ottawa, have already produced 10,000 tons of ore. The ore is a dense rich magnetite, which requires roasting to expel sulphur, but it is low in phosphorus. The following are analyses of raw and of calcined ore :—

	Raw.			Calcined.			
Iron . .	58.37	62.15	61.99	62.50	62.52	62.87	63.24
Sulphur . .	1.46	0.97	2.406	0.521	1.167	2.221	1.08
Phosphorus . .	trace	0.0075	0.006	0.004	...	0.014	...
Silica . .	11.45	8.52	7.32	...	...	...	...

The latest experiments with the calcining furnaces have reduced the sulphur to 0.279 per cent.

In Lanark and Renfrew counties some ores are found. Samples from the outcrops showed :—

	Magnetite.	Hæmatite.
Iron	65.31	66.00
Phosphorus	0.017	0.06

Still farther west of Ottawa, in Ontario, magnetite is found with its phosphorus under the Bessemer limit. At present the magnetites have mostly been developed near Ottawa; and in view of American practice, these ores might profitably be smelted, although they carry a large proportion of sulphur. Magnesians, or pure limestone, abounds, so that flux can readily be obtained. The principal difficulty is with the fuel, and the author proceeds to investigate the cost and the sources whence it could be obtained. The cost of producing pig iron is calculated at £2, 18s. 4d. per ton; fuel costing £1, 7s. 1d.; ore, 17s. 8½d.; flux, 2s. 1d.; and labour, &c., 11s. 5½d.

Iron Ore of Vancouver Island.—Dr. G. M. Dawson * states that

* *Report of the Geological Survey of Canada for the year 1887-88 (1889), I. p. 100 R.*

the magnetite deposits at Sooke Harbour, Vancouver Island, can be traced for some distance in a N.E. to S.W. direction. Though apparently a stock-work, in places the ore is nearly 20 feet wide. The country rock is a coarsely crystalline diorite containing much hornblende.

Iron Ore in New York.—Mr. J. Birkinbine describes * the deposit of iron ore at Lover's Hole, Port Henry, where, in the centre of a mass of pure ore, a mass of crystalline magnetite was found in a space 20 feet wide and 10 to 12 feet thick. The output of nearly 40,000 tons of ore taken from this opening shows the average iron contents to be 68·6 per cent., and the average phosphorus contents to be 0·033 per cent. These averages represent all of the ore removed from this working, and are obtained from thirty analyses by Mr. J. R. Woodbridge. It is probable that the highest percentage of iron—namely, 72 per cent.—found in the early development of this working, was obtained from a sample in which crystals were abundant, while the lowest iron contents—namely, 61·2 per cent.—was evidently determined from an excess of lean ore or the presence of wall rock after the workings had been considerably extended; for the next lowest analysis shows 65·10 per cent. of iron. The laboratory dates of these two analyses indicate this to be the case. The one determination showing 72 per cent. of iron was checked by a second analysis. There are also two analyses between 71 and 72 per cent., and seven between 70 and 71 per cent. One-third of the determinations, therefore, indicate 70 per cent. or over of iron. The variations in the phosphorus contents are from 0·011 to 0·060, but the two instances in which the phosphorus reached the latter figure showed in the same samples 67·20 and 68·45 per cent. of iron, so that in no instance does analysis show that the phosphorus exceeds one part in 1120 of iron.

As an appendix to the above, the *Journal of the United States Association of Charcoal Iron Workers*† describes the Crown Point mines in Essex County. An analysis communicated by Mr. A. L. Inman gave the following results:—

F ₂ O ₃ .	FeO.	MnO.	Al ₂ O ₃ .	CaO.	MgO.	P ₂ O ₅ .	S.	SiO ₂ .	Total.
47·38	21·32	0·10	1·97	1·18	0·36	0·08	0·02	27·48	99·89

The metallic iron is 49·74, and phosphorus 0·035 per cent. Mining

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† Vol. viii. pp. 322-331. :

has been carried on in this group for thirteen years, during which 1,041,019 tons have been produced.

The Chateaugay mines in Clinton County produce Bessemer ore containing 52·47 per cent. of metallic iron, and showing on analysis:—

Fe ₂ O ₃ .	FeO.	MnO.	Al ₂ O ₃ .	CaO.	MgO.	SiO ₂ .	P ₂ O ₅ .	S.	Total.
49·98	22·49	0·17	1·36	4·05	1·97	18·45	0·068	0·052	98·59

In the same county are the Palmer Hill mines and the Arnold Hill mines. Two analyses of each are given, the results being as follows:—

Fe.	O.	Al ₂ O ₃ .	CaO.	MgO.	H ₂ O.	P ₂ O ₅ .	P.	SiO ₂ .
51·47	19·62	1·86	0·08	0·62	0·43	0·042	...	25·42
38·80	14·79	2·20	0·26	0·80	0·45	0·05	...	42·49
59·92	...	...	...	...	...	...	0·070	...
61·28	...	...	...	...	...	...	0·113	...

Iron Ore Beds of Minnesota.—Mr. N. H. Winchell,* the State geologist of Minnesota, is of opinion that the beds of iron ore of the Animike correspond in age and relation to the iron ore beds in the Taconic formation of Western New England. Mr. J. D. Dana,† however, points out that this formation has no such beds, the only iron ore being limonite of secondary origin, except some local bodies of iron carbonate. The Taconic limestone, too, in which the limonite deposits and iron carbonate occur, has afforded in some places calciferous or Trenton fossils. In 1889, for example, Mr. W. B. Dwight‡ made discoveries of this kind in the Copake-Millerton-Amenia limestone belt, in which are several of the great limonite deposits, and at Amenia, the largest body of iron carbonate yet observed in the Taconic region. Here the fossils of the limestone were species of *Ophileta*, *Orthoceras*, and *Cyrtoceras*.

Tennessee Iron Ores.—Mr. J. J. Traver§ gives the following analyses of some Tennessee iron ores:—

	Iron.	Silica.	Manganese.	Phosphorus.
Cannon mine . . .	67·91	2·01	...	0·06
Hodge mine . . .	{ 42·23	11·00	8·91	0·175
	{ 57·07	5·35	...	0·225
Hardin	54·23	11·55	...	0·083
Hust	52·26	3·50	4·23	0·336

* *Seventeenth Annual Report of the Geological Survey of Minnesota.*

† *American Journal of Science*, vol. xxxix. p. 67.

‡ *Ibid.*, vol. xxxviii. p. 150.

§ *Journal of the United States Association of Charcoal Ironworkers*, vol. viii. pp. 331-332.

Two manganese ores from Stony Creek, Carter County, have the following composition :—

	Iron.	Manganese.	Silica.	Phosphorus.	Copper.
Taylor Bank .	3·42	48·91	2·50	0·216	present.
Garland Bank .	4·85	46·44	5·95	0·183	present.

Iron Ore at Middlesborough, Kentucky.—Mr. C. R. Boyd* gives a geological section of the Middlesborough district in Kentucky, to show the distribution of iron ore and coal. The coal strata lie nearly level, and the ore deposits are found towards the south-east, dipping sharply to the north-west. The fossil ores occur in three veins, averaging three to five feet between the walls. Analysis of the ore gave the following results :—

SiO ₂ .]	Fe ₂ O ₃ .]	Al ₂ O ₃ .	MnO.]	P ₂ O ₅ .	S.	H ₂ O.	Total.
12·20	80·16	3·94	0·35	0·30	trace	3·10	100·05

A vein of Oriskany ore averaging 15 feet between the walls gave an analysis of 55·48 per cent. of iron and 0·066 per cent. of phosphorus.

Limestone as flux is abundant, and there are eleven to thirteen workable coal seams from which a good hard coke can be made. The cost of a ton of pig iron made from 56 per cent. ore is reckoned at £1, 6s. 10d., and made from 40 per cent. ore at £1, 13s. 9d.

Virginia Iron Ore.—Dr. W. H. Ruffner† states that the iron ore beds in Rockbridge County, Virginia, belonging to the Buena Vista Iron Company, have a general dip to the north-west of about 35°. There are several beds, four occurring in the great sandstone horizon, and the remainder, except some limestone ores, in the Upper Potsdam slates. These latter ores are abundant and easy to mine. By assay they show :—

Iron.	Phosphorus.	Silica.
51·411	0·222	12·622

The ores are almost free from sulphur. The cost of making coke pig iron is estimated at from 32s. to 48s. per ton.

* *The Engineering and Mining Journal*, vol. xlix. pp. 171-173.

† *Iron Age*, vol. xlv. p. 959.

The Mesabi Iron Ore Range.—This is a deposit of iron ore lying to the south of Tower, and within a few miles of the Duluth Iron Range Railroad. Work on this range has only recently been commenced. It is estimated that from 15,000 to 20,000 tons of the ore will be raised during 1890. The ore is stated to be rich in iron, and of Bessemer quality.*

Phosphorus in the Hudson River Carbonates.—Mr. J. Olmsted † describes the distribution of phosphorus in the Hudson River carbonates. The ores lie in a chain of low hills and dip about 45° east. The first opening was made in a low-grade Bessemer ore, containing about 35 per cent. of carbonate of iron and 0·03 per cent. of phosphorus; but this changed to a non-Bessemer ore of very irregular composition at the other end of the deposit. No crystals of apatite were found in the roasted ore, but the author picked out a lead-coloured mineral which appeared to run in veins, and contained about 3 per cent. of phosphorus. This material was as hard as flint and broke off in flakes; it appeared to be true apatite. In the true Bessemer ore but little of this substance was found. The author's researches were instigated by the publication of Mr. D. H. Browne's paper on the distribution of phosphorus in the Ludington mine. ‡

Iron Resources of Colorado.—A sketch of the iron ore resources of Colorado is given by Professor R. Chauvenet. § A vein of ore, carrying 36 to 38 per cent. of iron, and 36 per cent. of titanitic acid, is found in archæan rock in Boulder County, close to rich silver veins. This ore is useless for iron production, but shows the wide diffusion of titanium. This county was the first to produce iron in Colorado; concretionary iron ores from the Cretaceous strata having been used.

In Park County the formation of bog iron ore is well seen in some tributaries of the South Platte River. The streams are strongly chalybeate, but deposit all their iron in the marshes at the bottoms of the valleys. An analysis of the ore gave—

SiO ₂ .	Fe ₂ O ₃ .	P ₂ O ₅ .	CaO.	H ₂ O and Organic Matter.	Total.
7·13	67·55	1·82	1·22	22·37	100·09

* *Iron Age*, vol. xlv. p. 999.

† *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

‡ *Journal of the Iron and Steel Institute*, 1889, No. II. p. 325.

§ *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

The magnetite of the Calumet mine, Chaffee County, appears to be the result of oxidation of pyrites; it lies in a conglomerate apparently belonging to the Lower Silurian. The mine has been largely worked, and gives a true Bessemer ore. The ores shipped show 0·008 per cent. of phosphorus, 0·1 to 2 per cent. of sulphur, and 50 to 63, or an average of 57 per cent., of iron. In Fremont County, a titaniferous ore is supplied for puddling purposes. In Saguache County over 100,000 tons of limonite have been taken from the Hot Springs mine. The ore contains 43 per cent. of iron, 20 per cent. silica, and 13 per cent. water; it also contains a small amount of barium, and only 0·03 per cent. of phosphorus. In the Leadville district, the Breece and Hull mines are the only ones of importance. The Breece ore is of Lower Carboniferous age, at the contact of two beds of porphyry, and contains 60·5 per cent. of iron, 5·80 of silica, and 0·03 of phosphorus. The Hull ore is used to produce spiegeleisen, containing 22 to 24 per cent. manganese; its analysis shows 32 per cent. of iron and 17 per cent. of manganese. The ores of Gunnison County are also described.*

The Sigua Iron Mines, Cuba.—Mr. T. H. Graham† states that the Cuban Bessemer iron ore range extends along the flanks of the Sierra Maestra, eastwardly from Santiago de Cuba, for a distance of about 15 miles. The output of the Juragua mines in this district amounted in 1889 to 260,000 tons, and it is anticipated that in 1890 the quantity will reach 500,000 tons. The ore shipped to the United States contains—

Iron.	Phosphorus.	Sulphur.
62	0·03	0·30

The adjacent Sigua mining concession covers 890 acres; it is situated about $3\frac{1}{2}$ miles from the Caribbean Sea, at the eastern extremity of the iron ore range. At the Arroyo la Plata one of the deposits exposed shows a sheer vertical height of 450 feet above the bed of the ravine, with an average width of 150 yards. The ore is found to contain—

Iron.	Phosphorus.	Sulphur.
66	0·016	0·150

There are a number of extensive outcrops, two of which were estimated to be so large as to show between them at least 500,000 tons of ore in sight.

* See *Journal of the Iron and Steel Institute*, 1889, No. II. pp. 323-324.

† *Iron Age*, vol. xlv. p. 997.

At the Juragua mines the ore is found to be of the same composition in the deep as at the surface, and it is probable that this will be the case at the Sigua mines also. The cost of mining, royalties, &c., is estimated at about 4s. per ton f.o.b., or about 16s. at New York.

Iron Ore in the Argentine Republic.—Deposits of iron ore were discovered near the town of Catamarca, in the Argentine Republic, in the year 1874, and they appear, according to Mr. H. D. Hoskold,* to be of considerable extent and value. Up to the present time, however, they have not been worked to any large extent. An analysis of the ore by Dr. Kyle gave the following results:—

Fe.	O.	Al ₂ O ₃ .	MgO.	SiO ₂ .	TiO ₂ .	S.	H ₂ O.	Total.
52·64	19·18	1·80	2·46	6·40	16·70	0·10	0·72	100·00

Of the following analyses, the first is by Mr. Riley, the second by Dr. Kyle:—

Fe ₂ O ₃ .	FeO.	Al ₂ O ₃ .	SiO ₂ .	CaO.	TiO ₂ .	MnO.	Mn.	S.	H ₂ O.	Total.
52·21	14·89	5·40	2·55	...	18·17	0·97	4·28	...	0·93	99·40
63·57	...	1·58	23·26	0·33	...	...	...	0·24	11·10	100·08†

The first of these contains 48·25 per cent. of metallic iron. Other analyses show ores without titanous acid or phosphorus with 44·53 up to 63·96 per cent. of metallic iron. An abundant supply of wood for charcoal exists near the deposits. The rocks which contain the ore are mainly granites, gneiss, and schists.

In the province of San Luis, ore is found whose general character is shown by the following analytical results:—

Fe ₂ O ₃ .	FeO.	MnO.	MgO.	TiO ₂ .	SiO ₂ .	Al ₂ O ₃ .	Total.
23·41	64·20	0·80	2·35	3·64	4·20	1·40	100·00

Iron Ore from the Orinoco.—The iron ore deposit situated about 18 miles from the mouth of the Orinoco River is about to be opened up. Assays of the ore show it to contain ‡:—

Iron.	Phosphorus.	Sulphur.	Silica.
63·94-69·65	0·006-0·033	0·01-0·18	0·5-0·7

Native Iron Sulphates from Chili.—Mr. J. B. Mackintosh§ gives the results of analyses of a series of iron sulphates, several of which

* *Mémoire Général sur les Mines dans la République Argentine*. Buenos Aires, 1889, pp. 188-193, 266.

† 100·00 in original.

‡ *Iron Age*, vol. xiv. p. 286.

§ *American Journal of Science*, vol. xxxviii. pp. 242-245.

have not previously been described. Four of the sulphates are well-known species. The first analysis refers to coquimbite, 1a being amethystine, crystalline and transparent, 1b amethystine, massive and translucent, and 1c white, massive and opaque. The analyses of these three varieties all lead to the same formula: $\text{Fe}_2\text{O}_3, 3\text{SO}_3, 9\text{H}_2\text{O}$. The other well-known species are (2) copiapite, specific gravity 2.118; (3) roemerite, brown, crystalline, specific gravity 2.15; (4) amarantite, red, crystalline, specific gravity 2.005.

Of the new minerals, the first (analysis 5) occurs associated with copiapite and amarantite in pulverulent orange flakes. Its formula is $\text{Fe}_2\text{O}_3, 2\text{SO}_3, 4\text{H}_2\text{O}$. *Ferronatrite* (analysis 6) occurs in stellate groups of a pale whitish-green colour, associated with copiapite and coquimbite. Associated with these minerals are several white pulverulent sulphates, which are apparently alteration products. Analyses are given (Nos. 7, 8, 9) of three of these powders.

	SO_3 .	Fe_2O_3 .	Al_2O_3 .	FeO.	Na_2O .	K_2O .	Insol.	H_2O .
1a.	43.40	22.17	4.39	...	0.25	...	...	29.79
1b.	42.90	26.10	1.65	...	0.27	...	...	29.08
1c.	42.32	28.10	...	...	...	...	...	28.67
2.	39.03	29.16	...	1.56	0.31	...	...	29.94
3.	40.19	19.40	...	9.52	0.14	...	...	30.85
4.	36.15	35.69	0.21	...	0.51	...	...	27.44
5.	41.24	41.22	...	...	...	...	...	17.54
6.	50.25	17.23	0.43	...	18.34	0.40	2.00	11.14
7.	38.00	12.16	...	22.51	0.58	...	...	26.75
8.	47.90	5.64	0.65	30.81	4.42	...	...	10.58
9.	45.61	5.14	...	35.05	0.33	...	...	13.87

Analyses of iron sulphates are also given by L. Darapsky,* his results being given in the following table:—

	a.	b.	c.	d.	e.	f.	g.
Fe_2O_3 . .	30.00	35.62	36.86	28.18	32.13	18.22	18.13
Al_2O_3 . .	...	...	...	2.95	...	3.01	...
FeO . . .	...	...	...	...	...	...	8.30
Cu_2O . .	8.27	...	...	...	...	...	...
SO_3 . . .	33.05	36.20	36.85	38.47	30.60	41.15	36.19
H_2O . . .	26.81	28.33	26.34	29.50	35.74	27.64	34.30
CaO . . .	...	...	...	trace	...	4.10	0.45
MgO . . .	...	...	...	0.15	...	5.62	...
Insoluble .	1.83	...	0.53	0.78	1.41	...	2.63
Totals .	99.96	100.15	100.58	100.03	99.88	99.74†	100.00

* *Jahrbuch für Mineralogie*, 1890, vol. i. pp. 49-70.

† 99.84 in original.

(a.) Paposite, a mineral first described by Stüven, who assigned to it the formula $\text{Fe}_2\text{O}_3, 2\text{SO}_3, 4\text{H}_2\text{O}$. The author's formula is $2\text{Fe}_2\text{O}_3, 3\text{SO}_3, 10\text{H}_2\text{O}$. (b.) Amarantite, first described by Frenzel, formula $\text{Fe}_2\text{O}_3, 2\text{SO}_3, 7\text{H}_2\text{O}$. (c.) Hohmannite, a mineral also described by Frenzel, is intimately mixed with a laminated mass which gave on analysis the results stated in the table. (d.) Copiapite, formula $\text{Fe}_2\text{O}_3, 2\frac{1}{2}\text{SO}_3, 8\text{H}_2\text{O}$. (e.) Fibroferrite, formula $\text{Fe}_2\text{O}_3, 2\text{SO}_3, 10\text{H}_2\text{O}$. (f.) Rubrite, formula $\text{Fe}_2\text{O}_3, 2\text{SO}_3, 3\text{H}_2\text{O}$. (g.) Botryogen, formula $2(\text{Fe}_2\text{O}_3, 3\text{SO}_3), (\text{FeO}, \text{SO}_3), 32\text{H}_2\text{O}$.

G. Linck * gives an exhaustive description and a number of analyses of iron sulphates found near Copiapo:—

	1.	2.	3.	4.	5.
Silica.	1·29	...	...	...	...
Sulphuric anhydride	41·48	39·83	38·91	32·94	38·47
Ferric oxide	27·86	27·66	30·10	32·43	17·62
Alumina	trace	trace	trace	trace	1·02
Magnesia	trace	trace	...	trace	...
Water	28·77	31·55	30·74	34·32	34·10
Lime . . . . .	...	0·40	trace	0·40	trace
Insoluble . . . . .	...	...	...	0·63	...
Totals	99·40	99·24	99·75	100·72	100·27
Specific gravity	2·10	2·11	2·10	1·85	2·10

1. Coquimbite; 2. Quenstedite; 3. Copiapite; 4. Stylpticitic; 5. Roemerite, containing also 9·06 per cent. of ferrous oxide.

Manganese Ores of Dillenburg.—An important manganese mining industry has been carried on for several years in the valley of the Scheldebach, near Dillenburg. According to A. Schneider,† the ore principally worked is a mixture consisting largely of klipsteinite, and containing SiO_2 , Mn_2O_3 , MnO , and H_2O . It is probably the result of the alteration of a manganous silicate, which still forms part of the mass. The analysis of this silicate (analysis I.) approximates to that of the stratopëite of Pajsberg. This dark amber-coloured mineral is accompanied by a dark red ore (analysis II.), the specific gravity of which is 2·675. Pockets of psilomelane, manganite, and wad occur in the ore, as well as nickel-bearing iron pyrites, copper pyrites, and native copper. An anthracite is also met with. This has probably reduced the native copper, and consists of 72·67 per cent. of carbon, 3·38 per

* *Zeitschrift für Kristallographie und Mineralogie*, vol. xv. pp. 1-28.

† *Jahrbuch für Mineralogie*, 1890, pp. 19-22. ¶

cent. of hydrogen, and 20·40 per cent. of ash-forming constituents. Anthracite is similarly met with in the neighbouring red hæmatite mines. At the contact of the manganese ore deposit with the diabase, a new mineral, *inesite*, has been found. It is flesh-coloured, radiated, and has a hardness of 6. In composition (analysis III.) *inesite* somewhat resembles hydro-rhodonite.

	SiO ₂ .	Fe ₂ O ₃ .	Al ₂ O ₃ .	FeO.	MnO.	CaO.	MgO.	CO ₂ .	H ₂ O.	Total.
I.	35·64	3·02	2·59	...	39·26	1·75	1·31	0·60	13·94	98·11
II.	30·21	12·49	2·30	...	29·16	6·04	0·98	2·40	16·62	100·20
III.	43·92	...	0·29	0·69	38·23	8·00	0·28	...	8·49	99·90

Manganese Ore in Russia.—The world's production of manganese ore amounted to 84,000 tons in 1884, a production which annually increased until in 1887 it amounted to 265,000 tons. Of the countries producing manganese ore, Russia takes the first place, its production having amounted in 1886 to 74,399 tons, of which quantity 69,481 tons were produced in the Caucasus, and 4918 tons in the Ural.

The extensive deposits of the Caucasus were first worked in 1879. They occur in the Governments of Kutais, Tiflis, Jellesawetpol, and Baku, as beds of varying thickness in Miocene or Eocene sandstones overlain by shale. The ore-bearing stratum attains a thickness of as much as 26 yards, and contains a number of distinct beds of manganese ore, separated by partings of talcose clay. At Tschiaturi there are eight beds. The deposits have been laid bare by erosion, and are cheaply worked.

The ores from the Scharopan district, which yields almost the entire production of the Caucasus, contain 54 to 55 per cent. of manganese, 1 per cent. of iron, and 0·16 per cent. of phosphorus. The Tiflis ores contain only 44 per cent. of manganese, but have the advantage of a position adapted for easy transport. A ton of dry ore, with 54 per cent. of manganese, costs at Rotterdam about £3, 15s. 6d. The cost of production and profit form 13·5 per cent. of this amount, the remainder being the cost of transport.*

Manganese Ore in the Argentine Republic.—According to Mr. H. D. Hoskold,† manganese ore is found in the province of San Luis, Argentine Republic, in gneissic rocks, with the following composition:—

Mn ₂ O ₃ .	MnO ₂ .	Fe ₂ O ₄ .	Al ₂ O ₃ .	CaO.	MgO.	SiO ₂ .	H ₂ O.	Total.
50·50	27·79	7·49	2·00	1·00	0·52	8·00	2·70	100·00

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 33.

† *Mémoire Général sur les Mines de la République Argentine*. Buenos Aires, 1889, pp. 275-277.

Recent Researches on Meteorites.—S. Meunier* describes a meteorite which fell on September 22, 1887, at Phu-Hong, in Cochin China. It has a granular fracture of a violet-grey colour. Under the microscope, it is seen to consist of a transparent matrix, containing opaque needles and granules. The specific gravity of the meteorite is 3·601. Of the mass, 35·37 per cent. is magnetic, the composition of this portion being as follows :—

Iron.	Nickel.	Cobalt.
91·22	9·05	trace

When treated with hydrochloric acid, 29·62 per cent. of the mass was found to be soluble and 35·12 insoluble. The former portion is composed of 40·09 per cent. of silica, 45·97 per cent. of magnesia, and 14·00 per cent. of ferrous oxide; whilst the insoluble portion has the following composition :—

SiO ₂ .	MgO.	CaO.	Na ₂ O.	FeO.	Al ₂ O ₃ .	Cr ₂ O ₃ .
63·60	28·48	1·91	0·87	4·10	1·22	0·92

Mr. J. E. Whitfield† describes a mass of meteoric iron weighing 72 lbs. found on La Bella Roca, a peak of the Sierra de San Francisco, in the State of Durango. The date of its discovery and the name of the finder are unknown. The composition of the metallic portion is as follows :—

Fe.	Ni.	Co.	P.	S.	C.	Total.
91·48	7·92	0·22	0·21	0·21	0·06	100·10

On one side of the meteorite there are large deep pittings, greater in diameter just below than immediately at the surface. Remains of a substance that evidently originally filled the cavities proved to be troilite having the composition :—

NiS.	FeS.	Fe.
2·13	85·27	9·37

The exposed portions of the troilite were greatly decomposed, and gave on analysis :—

NiS.	FeS.	Fe ₂ O ₃ .	H ₂ O.
2·07	37·51	3·78	19·85

The deep pittings were probably formed by the removal of troilite nodules while the mass was hot, and by the subsequent weathering. Nodules of troilite occur throughout the mass, but the pittings have

* *Comptes Rendus de l'Académie des Sciences*, vol. cix. pp. 875–878.

† *American Journal of Science*, vol. xxxvii. pp. 439–440.

been formed only on the front side of the meteorite. Thin sections of the meteorite, when etched, show Widmanstätten figures and dark diagonal bands of troilite.

Dr. F. A. Genth * describes a meteoric iron which appears to have fallen in 1860 at a distance of ten miles from Cleveland, East Tennessee. Its original weight was about 232 lbs. The mean of three analyses gave—

Fe.	Ni.	Co.	Cu.	P.	S.	Total.	Sp. gr.
89.60	8.80	0.67	0.12	0.32	0.01	99.52	7.521

C. Friedheim † describes the meteorites of Alfianello and Concepcion. The analysis of the meteorite of Alfianello gave 7.92 nickel iron (I.), 7.78 troilite, 0.60 chrome iron, 37.38 olivine (II.), 46.29 bronzite and augite (III.) :—

	I.		II.	III.
Fe . . .	88.84	SiO ₂ . . .	34.92 ...	53.86
Ni . . .	10.09	Al ₂ O ₃ . . .	...	5.76
Co . . .	1.07	FeO . . .	13.79 ...	10.55
Mn . . .	0.26	CaO . . .	...	7.73
		MgO . . .	51.26 ...	21.68

These results differ considerably from those previously published by Maissen, Flight, and von Foulton.

The meteorite that fell in 1880 between Nogayá and Concepcion is briefly described by Websky and Daubrée. The complete analysis gave the results shown under IV., and that of the portion soluble in hydrochloric acid the results shown under V. :—

	SiO ₂ .	Al ₂ O ₃ .	Fe ₂ O ₃ .	Cr ₂ O ₃ .	MnO.	CaO.
IV. . . .	27.22	2.35	30.64	0.38	0.09	2.56
V. . . .	26.67	2.34	30.42	...	...	2.25

	MgO.	Alkalies.	Ni.	Co.	Cu. Sn.	Ignition.	Insol.
IV. . . .	19.24	0.18	1.61		trace	14.47	...
V. . . .	18.79	0.12	1.46	0.12	...	...	1.82

With ether, 0.21 per cent. of a yellow bituminous substance was extracted. It volatilised at 200°, and when burnt in oxygen yielded 1.56 per cent. of carbon and 14.03 per cent. of water. There was also contained in the meteorite 3.27 per cent. of sulphur, 0.064 per cent. of phosphorus, 2.08 per cent. of sulphuric anhydride, and 0.034 per cent. of nitrogen.

* *Jahrbuch für Mineralogie*, 1889, vol. ii. p. 42.

† *Sitzungsberichte der königlichen preussischen Akademie der Wissenschaften zu Berlin*, vol. xiii. pp. 345-367.

Dr. F. von Sandberger* describes a meteorite found at Carcote, in Chili. It was originally mistaken for silver ore. The main portion of the mass is of a light grey to whitish colour, and is as hard as quartz. The specific gravity of the mass, after removal of nickel iron, was found to be 3.466. In addition to minute grains of chrome iron ore, the meteorite contains grains of two distinct silicates. A portion, 0.476 per cent., of the meteorite was soluble in distilled water, and gave on analysis—

CaO.	MgO.	SO ₃ .	KCl, &c.
33.83	8.40	27.52	30.25

Hydrochloric acid dissolved the silicate, which formed 38.88 per cent. of the mass. This consisted of colourless grains, which behaved like olivine under the microscope, and which gave on analysis—

SiO ₂ .	MgO.	FeO.	Al ₂ O ₃ .
38.35	35.83	25.28	0.54

This is the composition of olivine fairly rich in iron. The second silicate formed 40.73 per cent. of the meteorite. It gave on analysis—

SiO ₂ .	Al ₂ O ₃	FeO.	MgO.	CaO.	Na ₂ O.	K ₂ O.
57.43	5.20	10.07	20.36	2.85	3.35	0.74

This is obviously an alkali-bearing compound of the diopside group, a mineral which has hitherto but rarely been met with. Black grains of chrome iron ore, disseminated throughout the meteorite, form but 1.39 per cent. of the mass. The troilite, which forms 5.83 per cent. of the whole, is not distinguishable from ordinary magnetic pyrites. The nickel iron gave on analysis—

Fe.	Ni + Co.	Mn.	Cu + Sn.	P.
87.08	8.85	1.44	0.60	2.03

This is similar to the composition of the nickel iron from the meteorite of Deesa. As the alteration-products contain the same elements in equal proportions, the ferric oxide, nickel oxide, and manganese oxide may be calculated as metal. This gives 8.36 per cent. of the mass, which, with 1.66 per cent. of unaltered nickel iron, represents 10.02 per cent. of the meteorite. Minute quantities of the rhabdite of G. Rose also appear to be present. The most remarkable substance, however, occurring in this meteorite is dull black, has great hardness (9), is not attacked by acids, and consists exclusively of carbon. In one place it forms a segregation 3 millimetres in breadth, and appears

* *Jahrbuch für Mineralogie*, 1889, vol. ii. pp. 173-180.

to be black diamond. Other carbonaceous matter is present, but has not been accurately estimated. The results of the investigation are of considerable interest, as this meteorite represents a new type for Chili, a country in which numerous meteorites have been found. Similar meteorites are, however, known in other districts. Thus, this meteorite resembles the Alfianello meteorite which fell on February 16, 1883, and probably also that of New Concord, Ohio.

The Carcote meteorite is also described by Dr. Will and Dr. Pinnow.*

A meteorite of carbonaceous nature which fell at Migheni, Russia, on June 9, 1889, has been examined by S. Meunier.† It has a greenish-black wrinkled surface, relieved by numerous small white crystals, and is very friable. Under the microscope a section shows crystals of magnesian pyroxene and olivine. Fine particles of iron and nickeliferous iron were separated by the magnet. The specific gravity is 2.495. About 85 per cent. is attacked by acids, and this portion consists mainly of silicate of magnesium and iron. Five per cent. of the meteorite consists of organic matter; an alcoholic extract showed the presence of a bright yellow resin. A cold aqueous extract of the meteorite shows the presence of about 2 per cent. of matter possessing novel qualities, which appear to approximate to those of certain metallic tellurates.

Mr. L. G. Eakins ‡ describes a fragment of the meteorite presented by Mr. R. T. Hill to the United States National Museum. It is of irregular shape, and weighs $5\frac{1}{2}$ lbs. It is hard, compact, and very tough. The stony mass is very uniform in structure, but under the microscope is seen to consist of olivine and enstatite, with a small quantity of a colourless felspar. The mass has a specific gravity of 3.543, and on analysis yielded—

SiO ₂ .	Al ₂ O ₃ .	Cr ₂ O ₃ .	FeO.	Fe.	NiO.	Ni.	Co.	CaO.
44.75	2.72	0.52	16.04	1.83	0.52	0.22	0.01	2.23
MgO.	K ₂ O.	Na ₂ O.	P ₂ O ₅ .	S.	H ₂ O.	Total.	Less O for S.	Total.
27.93	0.13	1.13	0.41	1.83	0.84	101.11	0.92	100.19

The metallic portion constituted 2.23 per cent. of the mass, and contained—

Fe.	Ni.	Co.	Total.
88.74	10.68	0.58	100.00

* *Berichte der deutschen chemischen Gesellschaft*, vol. xxiii. p. 345. *Nature*, vol. xli. p. 428.

† *Comptes Rendus de l'Académie des Sciences*, vol. cix. pp. 976-978.

‡ *American Journal of Science*, vol. xxxix. pp. 59-61.

The general composition of the meteorite is as follows:—

Metallic.	Troilite.	Soluble in Acids.	Insoluble.	Total.
2·23	5·03	39·84	52·42	99·52

The soluble portion appears to consist of olivine, and the insoluble portion of enstatite and a felspar of the oligoclase type.

II.—IRON ORE MINING.

The Poetsch Method of Shaft-Sinking in Iron Mines.—Mr. D. E. Moran* gives a detailed account of the freezing process as applied at Iron Mountain, Michigan, in sinking a shaft through quicksand. The ore body at the Chapin mine is heavily overlain by drift in the swampy centre of the valley, where a shaft was needed for drainage, ventilation, and haulage purposes. The drift consists largely of fine sand, having a little clay mixed with it, and containing also layers of gravel and boulders. It is about 95 feet thick, and the water-level was within 10 feet of the surface. Twenty-six 10-inch pipes were sunk at equal distances round a circle 29 feet in diameter, by means of pipe-sinking derricks. Through these pipes, 8-inch pipes, made of $\frac{3}{8}$ -inch plate, were inserted for the freezing process. The author describes the ammonia refrigerating plant and the brine used, and he also gives the results of experiments which were made to determine the rate and manner of freezing. The greatest freezing effect was at the bottom of the pipes; so the frozen wall had a batter of one in fifteen. Theoretical considerations show that when the sand contains 17 per cent. of water, 80 per cent. of the refrigerating effect is used in freezing it; but the amount of cold required cannot be calculated, as there is radiation above ground, conduction above and below the surface, and the flow of subsoil water. The character of the frozen sand probably varies. At Iron Mountain the sand is fine, and about 70 per cent. passes a 190-mesh screen. The tensile strength of briquettes averaged 431 lbs. per square inch, and the compressive strength 575 lbs. The material is like a fine-grained sandstone, and is difficult to work on account of the gravel and boulders. On the fifteenth day after starting the ice-machinery, excavation was commenced. After some time water began to leak in, and the passage of the water gradually increased the size of the leaks, so that it became necessary to flood the

* *The School of Mines Quarterly*, vol. xi. pp. 237-254.

shaft to equalise the pressure, while the wall was made good by the freezing machine. This operation had to be repeated when the bed rock was reached. The timber was put into position after all the framing had been done on the surface. Each set was hung from the one above it, tightened up and wedged into position, after which 4-inch lagging was put in, and wedges were driven between it and the wall. The timbering was carried 4 to 10 feet into the rock, and a tight joint was made with extra long timbers and grouting. Finally, the shaft was filled with water to equalise the pressure while the wall was thawing. This took fifty days, in spite of efforts to hasten the result. The alignment of the shaft was not disturbed, and the shaft was then carried on by the usual methods.

The process of sinking at the Iron Mountain is also described in the *Engineering and Mining Journal*,* and an illustration of the shaft is given.

Shaft Timbering.—The relative cost of the square set and cribbing systems of timbering shafts is calculated to be as follows:—

	Cents.
Shaft 5 by 10 feet, square sets 4 feet apart, timber 6 by 8 inches, planked with 2-inch thick boards.	
Two side pieces 6 by 8 inches, 10 feet long	80
Two end pieces 6 by 8 inches, 5 feet long	20
Two-inch boards for the sides	160
Two-inch boards for the ends	80
Two-inch boards for partitions	80
	<hr/> 420

This total, divided by four, gives 105 cents for each vertical foot of shaft.

	Cents.
Cribbing shaft 5 by 10 feet double compartment.	
Six pieces 4 by 6-inch timber, 10 feet long	120
Six end pieces 4 by 6 inch timber, 5 feet long	60
Two-inch boards for compartments	20
One middle piece 6 by 8 inches, 5 feet long	20
	<hr/> 220

Thus there is a difference of 115 cents in favour of the square set system, and this difference represents a considerable saving of time and labour in sinking shafts.†

* Vol. xlix. p. 85.

† *Engineering and Mining Journal*, vol. xlix. p. 139.

Hand-Boring for Ore with the Diamond Drill.—G. Nordenström * discusses the use of the diamond drill worked by hand-power in boring for ore. When the diamond drill originally came into use, it was thought that its advantages were such that it would be largely employed. Its use, however, proved comparatively costly, and efforts were then made to minimise these expenses as much as possible, in order to admit of its use in the Swedish iron ore districts. The author gives details of the expenses of a number of the bore-holes which have been recently made with the hydraulic diamond drill in Sweden. These experiments showed that the process was still too costly to enable it to compete with the methods in ordinary use, and efforts were then made to ascertain whether driving by hand would not give better results. A modified machine was therefore designed, and with this, during 1888 and a portion of 1887, borings were effected to a total depth of 2991·1 metres, or 98,137·2 feet, nearly the half of which took place at the Rörås, Wigelsbo, Dannemora, Bersbo, and Vinkärn mines. Each machine was worked by from 3 to 5 men. To a depth of 65 feet, 2 men suffice to produce the rotary movement of the tool, but from that depth onwards 4 men should be employed at the work. The depth bored in the shift of 8 or 9 hours varied with the different machines within the limits of 0·781 and 1·466 metre, the average being 1·100 metre. By working two 12-hour shifts per day, a depth of 50 metres may be reached in the month of 24 working days through hard rock and ore. This result is about five times better than that of the ordinary hand methods of working. The total cost per yard bored varied between 21s. and 25s. 6d.—little more than half that of ordinary methods.

Electrical Diamond-Boring Machine.—E. Gad † illustrates a diamond-boring machine driven by electricity. It was invented by Sullivan, and is manufactured by a Chicago company. It is so arranged that it can be installed in confined spaces in the mine, and employed for prospecting for ore in all directions. In construction, it is similar to other diamond-boring machines. The feed is regulated by different spur-wheels.

Hitherto for this type of machine three forms of motive power have been used—human labour, steam, and compressed air. To these, electricity is now added. The application of human power for working

* *Jernkontorets Annaler*, vol. xliv. pp. 161–175.

† *Dingler's Polytechnisches Journal*, vol. cclxxv. pp. 317–319.

small diamond-boring machines is still new, having been first employed by A. Craelius in Sweden in 1887. This method necessitates numerous labourers, and can consequently be recommended only in cases where labour is cheap. Although slow, the work is performed in a trustworthy manner for bore-holes in all directions up to 70 yards in length. Steam-power can only be used at the surface, since, apart from the difficulty of conducting steam into the mine, there is the disadvantage that the escaping steam vitiates the air of the mine, and attacks the timbering and the strata. Compressed air is well adapted for underground use, for it is easily conducted, and improves and cools the air of the mine. The engines required to produce the compressed air are, however, complicated, and not always easily obtainable.

In view of the extended application of electricity to mining operations, it is comparatively easy to install electrical motors in difficultly accessible mining districts. In such cases, Sullivan's diamond-boring machine may be advantageously employed. This machine necessitates a 3 horse-power motor, and the length of the bore-holes in any direction may amount to 100 yards. The pump attached to the machine is driven by the same motor.

Manganese Ore Mining.—At the Crimora mine, in Colorado, manganese ore occurs in a deposit which lies in an elliptical basin, about 500 feet broad by 800 to 900 feet long, in the Potsdam sandstone. The ore exists as lumps and masses in two, or possibly three, layers of yellow clay, the upper is 25 feet and the lower 30 feet thick, with 20 feet of barren ground between. The timbering in the mines is excessively heavy, and requires frequent renewal.

About 300 tons of material are mined daily; this stuff is washed, and yields 50 to 60 tons of manganese ore. The material as it comes from the mine, is crushed, and then passes to the "log" washer, which contains revolving shafts with spirally-arranged stirring teeth running in water. From this the half-washed material passes through a Bradford washer, which is a revolving drum with internal teeth, on to a conical screen. The ore which passes through the screen is further washed in jigs, and the coarse material is hand-picked. All the material is transferred by conveyers, and is not handled after it is sent to the crusher. Drawings of the mine and plant are given.*

Shipping Iron Ore.—Iron ore from the mines of Onton, near

* *American Manufacturer; Engineering and Mining Journal*, vol. xlix. pp. 333-335.

Bilbao, is carried to the ships by means of a staging running on a submerged railway, so that the ore can be shipped even during stormy weather. The coast is high and rocky, with a sloping shore inclining one in twenty. A track, 650 feet long and 20 feet wide, has been constructed on the shore to carry two lines of rails with $3\frac{1}{4}$ -feet gauge. A pyramidal iron staging, 70 feet high, is mounted on wheels, and runs on this quadruple track. The staging is worked automatically; it is connected to counter-weights consisting of loaded trucks running on an inclined way by means of a wire rope. The ore is brought from the mines by a wire rope-way to a shoot, down which it falls on to the staging. When sufficient ore is loaded, its weight overcomes the counter-weights and starts the stage out to sea; this movement closing gates in the shoot. The ship is moored fore and aft, and as soon as the loaded stage reaches it, the ore is automatically shot down slides into the hold.

The total cost of the apparatus is about £3600, and it has a capacity of 5000 tons per day. A load of 100 tons is carried at each journey.*

III.—MECHANICAL PREPARATION.

Iron Ore Concentration.—A form of trough washer for iron ore, much used in Pennsylvania, Virginia, Tennessee, and Alabama, is illustrated in the *Journal of the United States Association of Charcoal Ironworkers*.† The ore is discharged over a screen, the lumps are preferably crushed, and the ore is passed into the trough, where it is forced forward by a revolving toothed shaft against a stream of water. The shaft is placed at an inclination, so that about half of its length is submerged. The teeth are chilled iron, and are held on the shaft in removable sockets. Driving is performed from the front or discharge end by bevel gearing.

A rule is also given for calculating the value of concentrated ore. For each unit of increase in metallic iron, add one-twentieth of one cent per unit to the selling price; and for each unit that silica is lowered, add one-tenth of one cent. Thus if ore, before jigging, contains iron 42 and silica 22, and sells at 3 cents per unit or 5s. 1d. per ton, and if this ore contains, after concentration, iron 50 and silica 12, the increase in iron is 8 units, equivalent to 0·4 cent per ton, and the

* *Engineering and Mining Journal*, vol. xlix. pp. 132-133. The illustrations are borrowed from *La Ilustracion Española*.

† Vol. viii. pp. 349-353.

decrease in silica 10 cents equals 1 cent, so the selling value is 4·4 cents per unit, or 9s. 2d. per ton.

Wenström's Magnetic Ore Separator.—According to H. Dillner,* the Wenström magnetic ore separator in Sweden, driven by water-power, yielded 1456 tons of dressed ore in 116 days, at a cost of 1s. 7d. per ton, inclusive of £37 for interest on capital. Altogether 52,445 cubic feet of material from a very old tip was treated, yielding 1456 tons of ore and 728 tons of deads. From material raised direct from the mine 595 tons of ore were obtained by steam-power, at a cost of only 10d. per ton.

Two magnetic separators have recently been sent to Nepal from the Anboga Mechanical Works in Sweden. These separators are designed by J. Wenström, and are similar in size and general aspect to those described in this Journal.† The only difference is that the frame is arranged above the apparatus, which is suspended from it in brackets, and that the feed is altered to suit the fine materials to be worked. To each separator has been attached a dynamo giving 50 volts and 4 amperes for the magnetisation.‡

Washing Iron Ores.—The washing of iron ores in Sweden is still effected in a very primitive manner. In Wermland especially, the process is clumsy and expensive, as it is done by hand. In several districts magnetism has recently been successfully employed for separating the gangue from magnetite. The installation of magnetic separating machines is, however, costly.

The arrangement adopted by S. F. Mörstedt§ consists of various wooden tanks lined with iron, to which the small ore from the sorting-house is brought in trucks. The base of the tanks is formed of a thick perforated iron plate, which allows the water and fine ore and waste material to pass through. The washed ore is drawn out at the sides of the tanks to a table, and classified into coarse, fine, and worthless material. In comparison with former practice, this arrangement presents the following advantages: The work is lighter and consequently cheaper; on account of its cheapness this arrangement is suitable for small mines, and, unlike the magnetic classifier, it is adapted to the treatment of red hæmatite.

* *Jernkontorets Annaler*, vol. xliv. p. 347.

† *Journal of the Iron and Steel Institute*, 1889, No. I., p. 243.

‡ *Industries*, vol. viii. p. 463.

§ *Wermländska Annaler*; *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 7.

IV.—METALLURGICAL PREPARATION.

The Davis-Colby Ore Roaster.—Mr. S. G. Valentine * describes, with sketches, the Davis-Colby kiln for roasting iron ores with gaseous fuel. In general this kiln consists of two concentric shafts of brick-work. The annular space between the shafts contains the ore, and the products of combustion pass through flues into the central shaft. The inner shaft may be continued upwards to form the smoke stack, but it is preferably covered by a charging cone for the proper distribution of the ore, and the products of combustion are led out by a flue below to a separate chimney. In the outer wall are placed the fire arches, gas-flues, poking-holes, air-flues, and discharging orifices.

The height of the kiln, and the arrangement of fire arches and flues, depend on the nature of the ore under treatment. For hard dense magnetites the fire arches may be placed some distance apart, so that the ore can cool partially, and crack as it passes down. Two or more sets of fire arches are employed, and the burning gas from them passes through the thin annular sheet of ore, the fumes being speedily removed by the flues. Air has abundant means of access, and the temperature can easily be regulated, so that all the conditions required by the author in a previous paper † on the desulphurisation of iron ores are complied with.

Blast furnace gas may be used as the fuel in this kiln, but as a general rule the furnace will seldom supply enough waste gas to generate steam and heat the blast, as well as roast its own ore. It is therefore preferable to use producer gas.

Excellent results have been obtained in working with the open and porous ore at Katahdin, Maine, as shown in the following analyses :—

Iron	47·75	57·34	44·80	39·50	53·50
Phosphorus	0·017	0·025	0·04	0·035	0·034
Sulphur before roasting	3·90	1·29	0·98	2·50	2·48
Sulphur after roasting.	0·07	0·15	0·10	0·18	0·12

This roasted ore as a rule contains 0·05 to 0·20 per cent. of sulphur, averaging not over 0·10 to 0·12 per cent.

The following table shows the distribution of sulphur in roasted Cornwall ore. The first two samples are from a Gjers kiln ; the last three from a Davis-Colby kiln :—

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† *Journal of the Iron and Steel Institute*, 1889, No. II., p. 333.

Total Sulphur.	Sulphur as Sulphate.	Sulphur as Sulphide.	Ratio of Sulphur as Sulphate.
Per cent.	Per cent.	Per cent.	Per cent.
1·133	0·283	0·850	24·977
1·380	0·135	1·245	9·782
0·602	0·105	0·497	17·44
0·798	0·318	0·480	39·85
0·596	0·281	0·315	49·14

As much as 40 per cent. of fine ore may be treated in this kiln if it is properly mixed with the coarse stuff. Clinker is seldom formed, as the temperature is readily adjusted. The kiln at Katahdin is 20 feet high and 15 feet diameter, and roasts about 40 tons per day. At Colebrook and the Cornwall anthracite furnaces the output is 75 to 90 tons per day. Kilns of the latter capacity are erected by contract at £600 including royalty.

REFRACTORY MATERIALS.

Bauxite.—O. Vogel * enumerates the following localities at which bauxite is found :—Departments Var and Bouches du Rhône, L'Hérault and L'Ariège, in France ; Irish Hill and Glenravel, in Ireland ; Hadamar, Mühlbach, Klein-Steinheim, Langsdorf, in Germany ; and, lastly, a locality in French Guiana. Besides these there are the well-known Alpine localities.

In the following table of analyses, the principal constituents only are given. Besides these, there are small quantities of lime, magnesia, sulphuric anhydride, phosphoric anhydride, titanio anhydride, vanadic anhydride, alkalies, and traces of manganese.

	Alumina.	Ferric Oxide.	Silica.	Loss on Ignition.
Woehein (Carinthia) calcined	82·48	5·60	9·75	...
"	63·16	23·55	4·15	8·34
"	72·87	13·49	4·25	8·50
"	29·80	3·67	44·76	13·86
Feistritz	64·25	2·40	6·29	25·74
"	64·60	2·00	7·50	24·70
"	54·10	10·40	12·00	21·90
"	44·40	30·30	15·00	9·70
Pitten	53·00	24·20	7·50	13·10
"	44·10	37·20	4·70	12·00
Wöllersdorf	49·90	29·58	7·40	12·43
Galicia	76·89	4·11	8·11	7·08
Mühlbach	32·46	38·04	6·68	17·90
"	45·77	18·97	6·41	27·61
"	55·61	7·17	4·41	32·33
"	57·62	4·24	7·00	26·99
Klein Steinheim	56·02	6·19	10·97	26·42
Giessen	60·10	14·70	3·00	24·00
Wetterau	51·86	15·14	5·10	27·90
Vogelsberg	42·60	2·90	29·20	25·00
Langsdorf	50·85	14·36	5·14	28·38
"	49·02	12·90	10·27	25·91
Baux	75·00	12·00	1·00	12·00
"	60·00	25·00	3·00	12·00
Ireland	52·94	2·58	4·82	30·94
"	48·12	2·36	7·95	40·33
"	43·44	2·11	15·05	35·70
"	61·89	1·96	6·01	27·82
"	73·00	4·26	2·15	18·66

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. pp. 394-397, 408-410, 417-418. *Dingler's Polytechnisches Journal*, vol. cclxxv. p. 256.

Blasting Limestone.—The Glendon Iron Company of Easton, Pennsylvania, obtain their limestone by one large blast about every year. The quarry has a vertical face about 120 to 160 feet high, a gallery is driven 50 feet back from the base, and then at right angles on either side for a total distance of 135 feet. Four charges of powder in lots of 8000, 5000, 3000, and 4000 lbs. are placed in chambers 5 feet below the tunnel. The tunnel is filled up, and the charges fired by electricity. It is estimated that 60,000 tons of limestone are dislodged.*

Graphite for Crucibles.—In some notes on Styrian steel, Mr. F. Korb and Mr. T. Turner† give the following analysis of graphite from Kaisersberg, which is used for making crucibles:—

C.	SiO ₂ .	Clay.	Fe ₂ O ₃ .	CaO.	MgO.	K ₂ O.	Na ₂ O.	S.	P ₂ O ₅ .	H ₂ O.	Total.
77.95	13.04	6.12	0.44	0.08	0.07	0.43	0.15	trace	0.01	1.95	100.24

Manufacture of Graphite Crucibles.—In his treatise on the Metallurgy of Steel, Mr. H. M. Howe‡ gives a description of the manufacture of graphite crucibles. The information was drawn from a private communication by Mr. W. F. Downs of the Dixon Crucible Company, and from articles by Dr. J. C. Booth.§ Mr. Downs uses 50 per cent. of graphite, 33 of air-dried clay, and 17 of sand. Ceylon graphite is generally used; the laminated or fibrous varieties are preferred, as they bind the clay firmly. The graphite is ground between millstones, so as to pass through screens of from 40 to 100 mesh; if it is too coarse, the crucible is apt to be too porous; if it is too fine, the crucible is too dense, and is apt to crack. Fat refractory clay, such as the German "Klingenburg" or "crown" brand, is used. The sand should be rather coarse, passing a screen of 40 meshes to the linear inch; burnt infusible clay is as good, as it simply acts to assist drying and to form a hard skeleton.

The clay is made into a thin paste with water, the sifted sand and graphite are mixed in, and the whole is passed several times through a pug-mill, after which it is tempered for a few weeks in a damp situation. Weighed lumps of the tempered mass are kneaded and moulded on a wheel. Moulding is said to be better than simple pressing, as the

* *The Engineering and Mining Journal*, vol. xlviii. p. 495, one illustration.

† Paper read before the *South Staffordshire Institute of Iron and Steel Works Managers*, November 27, 1889; *Iron*, vol. xxxv. p. 72.

‡ *The Engineering and Mining Journal*, vol. xlviii. pp. 298-299.

§ *Journal of the American Chemical Society*, vol. vi. p. 283; and vol. vii. p. 4.

graphite flakes are arranged tangentially and bind the mass better. The crucibles are left in the plaster moulds for three hours, so that the plaster can absorb part of the moisture; they are then dried for about a week at a temperature of about 70° to 80° F., and are burnt in seggars in a common pottery kiln. In America anthracite is first used, and the firing is finished with long flaming wood to heat the upper parts of the kiln. Burning takes a week, and the temperature reaches about 1350° C. In burning, the graphite of the surface is removed; but if the drab coating is very thick, the crucible has been exposed to oxidation; if the coating is black, the crucible is probably underburnt.

Dolomite for Converter Linings.—Mr. T. W. Robinson * gives the following analysis of the dolomite used at the Stenay Steelworks for the lining of the Robert converter:—

CaO.	MgO.	Al ₂ O ₃ .	Fe ₂ O ₃ .	CO ₂ .	SiO ₂ .
41.35	9.50	0.36	0.54	48.0	0.45

Basic Lining for Bessemer Converters.—For a basic lining for Bessemer converters, E. Bertrand,† of Kladno, Bohemia, grinds dolomite or limestone thoroughly, mixes it with water, and, with or without an adhesive substance like molasses, forms it into bricks. The latter are burnt at a white heat for about forty-eight hours in a kiln. These burned bricks are again ground and mixed with 10 to 12 per cent. of tar, the product being used to ram up in the converter. It is claimed that the preparatory for bricks, the baking of the latter, and grinding the burned brick, yield a product more homogeneous than can ever be obtained from cupola or kiln-burned dolomite. Greater economy of material is attained, because in the latter case there is always a loss of the fine stuff, which must be thrown away, as it cannot be freed from cinder. This plan has been adopted by the Pottstown Iron Company, Pennsylvania.

Chrome Iron Ore Linings.—During the International Congress of Metallurgists at Paris, M. Rémaury submitted some data relating to the use of chrome ore linings by Messrs. Bell Bros. Pig iron averaging 3.60 per cent. of carbon, 1.8 to 2.5 per cent. of silicon, 1.5 to 1.6 per cent. of phosphorus, 0.06 to 0.02 per cent. of sulphur, and 0.5 to 0.6 per cent. of manganese, is worked in a chrome-lined open-hearth furnace, with scrap and previously roasted ore. Sometimes one-fourth

* *Iron Age*, vol. xliv. p. 674.

† *Iron and Coal Trades Review*, vol. xl. p. 246.

Bilbao ore is employed. The chrome ore lining resists well, both for silica and silicious slag, and remains neutral to strong bases. The pieces of chrome ore for the lining are bound by a little lime mortar. The bottom is made when the furnace is cold. The author, as a proof of the life of the chrome ore lining, states that one furnace at Alais, France, has been running with the same bottom for three years.

At the Port Clarence Works, the charge consists of 10 tons of pig iron, 3 tons of iron scrap, and 2 tons of steel scrap, to which limestone and ore are afterwards added. After melting for two to five hours, the slag is removed, carrying with it 50 per cent. of the phosphorus. More ore is then added. The total time required for one charge is nine and a half to ten hours. The ferro-manganese, of which 0·7 to 0·8 per cent. is used, is added in the casting ladle. The steel produced contains only 0·02 to 0·04 per cent. of phosphorus. It contains also a small quantity of chromium, to the presence of which the excellent mechanical tests obtained are partly attributed.

H. Portter* refers to the use which has been made of chrome iron ore as a dividing material between the acid and basic portions of a basic open-hearth. It was soon found that at high temperatures chrome ore softens, and that when in this softened condition the weight of the silica masonry built upon it, and that of the furnace arch, squeeze the chrome ore out of position, the result being finally direct contact between the acid walls and basic dolomite lining, and the destruction of the furnace. Magnesia brick is now used instead of the chrome ore, and the use of this latter material is gradually being altogether abandoned. The use of magnesia, on the other hand, is spreading, and the author points out that there is a growing tendency to build the side walls of the open-hearth furnaces of magnesite bricks to the spring of the arch of the roof, instead of making the upper limit of the basic lining at the level which the slag line occupies.

According to N. Kjellberg,† the chrome iron ore used as a basic lining at the Diosgyör Works in Hungary has the following composition :—

Cr_2O_3 .	$\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$.	SiO_2 .
50-52	39-45	2·5

together with some lime and magnesia. The ore is obtained from Bosnia.

* *Iron Age*, vol. xlv. p. 301.

† *Jernkontorets Annaler*, vol. xlv. p. 419.

FUEL.

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I.—CALORIFIC VALUE.

Pyrometry.—L. Knab* describes the pyrometer of F. de Saintignon. A current of water is led from a reservoir, maintained at a constant level, through a double tube which is inserted in the furnace. The temperatures of the inflowing and outgoing water are measured by thermometers, or may be automatically registered on a revolving drum, and the results may also be shown at a distance by electrical devices, such as a thermo-electric couple. If the height of the reservoir above the discharge be maintained constant, the flow will remain the same; any variation in pressure is shown by a manometer. The tubes are made of india-rubber to render the loss of heat as small as possible. An experiment showed a loss of 2 per cent. of the heat per metre when the temperature of the water was 19° C. above that of the air. The furnace tube is of copper, and the slight oxidation of the surface makes only a small difference, not more than 5 per cent. when the oxide was a quarter to a half millimetre thick.

II.—COAL.

Formation of Coal.—It is generally assumed that coal is formed by the alteration of cellulose, but Mr. W. A. Dixon† points out that

* *Le Génie Civil*, vol. xvi. pp. 327-331.

† *Proceedings of the Australasian Association for the Advancement of Science, Sydney*, through *Chemical News*, vol. lx. pp. 263-264 and 275-278. †

in most coals the woody fibre, which contains the greater part of the cellulose, is represented by almost pure carbon, forming the so-called "mother of coal" or mineral charcoal. As cellulose was so converted, it is unlikely that other portions of the same substance under similar conditions should be converted into bituminous matter. Particular varieties of coal are referred to different horizons for the conditions of their formation, but it is most probable that the nature of the vegetation itself has determined the nature of the coal to a greater extent than has previously been considered. The author's attention was drawn to this point by the examination of brown coals from New Zealand and Australia. These coals he divides into four classes—those containing up to 25 per cent. of fossil resin or retinite; those containing pyrites but no retinite; those containing no retinite nor pyrites, but having much combined sulphur; and those without retinite, pyrites, or sulphur. The first is evidently produced from highly resinous vegetation, and would produce bituminous coal; the second from non-resinous vegetation, the pyrites being formed by infiltration, and corresponding to the Lancashire stinking coal, or brassy coal from Scotland; the third is produced from vegetation containing much sulphur, such as modern *cruciferae*, and having no counterpart in existing coals; the fourth corresponds to splint, cherry, and other less bituminous coals.

The Joadja Creek deposit of kerosene shale contains three layers, namely, splint coal with much ash, shale, and at the top a fair bituminous coal. Thin partings only occur. The layers were thus deposited in orderly succession, and have been subjected to the same influences. Thus their qualities must be ascribed to a radical difference in the vegetation.

Analyses of cellulose and assays of various coals are then given, and particular reference is made to the nature of the products of distillation. The results seem to indicate that the bituminous part of coal arises from the resin, owing to the low ratio of fixed carbon and the low percentage of ash, which might be introduced by infiltration. Bituminous coals yielding low and valuable hydrocarbons on distillation are originally derived from aromatic resin-bearing plants, the resinous ligno-cellulose of which contributed to the result, whilst the cambium or more cellulosic portions were lost by decay, a little being converted into mineral charcoal. Cannel coal is probably derived from adipocellulose and ligno-cellulose, the former having considerable development in the plants, which, from the uniformity of the mineral, were

probably of small size. Torbanite and kerosene shales appear to be derived from some oil or wax-producing plant. At Joadja there is a ligno-cellulose below, a wax shale in the middle, and a resinous ligno-cellulose coal above.

Coal in the South-East of England.—The recent discovery of coal in the boring near Dover has again directed attention to the possibility of finding workable coal in the South-East of England. According to Professor W. B. Dawkins,* the physical identity of the coal-bearing districts of Somerset with those of Northern France and Belgium was recognised as early as 1826, but it was not till twenty-nine years later that the idea of the buried coalfields was advanced by Godwin-Austen. The Coal Commission of 1866–71 reported on the subject in the latter year, and in the following year the Sub-Wealden Exploration Committee was organised, and a boring was put down at Netherfield. With the exception of borings for other purposes, practically nothing more was done with the question till 1886, when Professor Boyd Dawkins and Mr. W. Whittaker separately indicated Dover as a suitable point for the exploratory bore-hole, which struck the coal-measures at a depth of 1160 feet from the surface, and a seam of good blazing coal 20 feet lower. The section shown was as follows:—

	Feet.
Lower grey chalk and chalk marl	500
Glauconitic marl	
Gault	
Neocomian or Lower greensand	
Portland strata	660
Kimmeridge clay	
Corallian rocks	
Oxford clay	
Calleonian	20
Bathonian or Lower oolites	
Coal measures, consisting of sandstones, clays, shales, and underclays with coal	

The boring finally settles the question, as far as its scientific and geological side is concerned. The commercial value of the deposits still remains to be proved; but it is most likely that the deposits are of considerable value from a comparison of the Somerset and South Wales fields on the west, and the fields of Belgium and Northern

* *Transactions of the Manchester Geological Society. Nature*, vol. xli. pp. 418–419. *The Contemporary Review*, 1890, pp. 470–478.

France on the east. The author also goes into the question of royalties.

Mr. W. Whittaker * describes the general geological structure of the country, and gives a map to show the positions of the known coal-fields to the east and the west of Kent. He then proceeds to describe the various borings in and around London, and draws the following conclusions:—The chalk is fairly regular in thickness below the Tertiary beds, but thickens considerably both north and south of the axial line. The Gault is also not irregular in thickness, but it thins out to the north and thickens southwardly. The Jurassic beds do not appear towards the north, and of eight borings which have reached still older rocks, four have ended in reddish rocks of doubtful age that may be New Red or may be Old Red Sandstone. In the latter case coal cannot be expected, unless it is brought in by a sharp oblique fold or overthrust fault. The other four borings all end in rocks older than the coal measures. The comparative evenness of the surface of the old rocks is remarkable, and they, therefore, do not form an underground ridge. Lastly, London appears to be on one of the cross uprisings, more or less at right angles to the main axis, which probably divide the carboniferous beds into separate basins. Beyond this district the coal measures have been proved at Burford, in Oxfordshire, at a depth of 1180 feet, and also carboniferous rocks occur in Northamptonshire. With the information derived from the Sub-Wealden and the Dover borings, there is a fair amount of certainty as to the thickness of the beds to be penetrated. It would appear that the coal occurs in basins, separated by cross uprisings of older rocks, in workable quantities and at workable depths, but the sites of these coal basins can only be found by experiments. The selection of a site for boring operations depends on the known or estimated thickness of the superincumbent beds. This is even more important than is the choice of a position where the oldest possible formation crops out.

The investigations of Professors Rücker and Thorpe † on the behaviour of the magnetic needle in various parts of the kingdom are then dealt with. Well-marked lines of disturbance are found, one of which runs along the Thames Valley to Reading, and then on to South Wales, with branches at various points. These disturbances of the needle are ascribed to the presence of basaltic or highly ferruginous rocks underground, and accordingly may be used to indicate the cross-uprisings of the older rocks.

* *Journal of the Society of Arts*, vol. xxxviii. pp. 543-546.

† *Proceedings of the Royal Society*, April 17, 1890.

In the discussion, unanimous opinions were expressed by Mr. W. Topley, Professor Rücker, and Dr. Archibald Geikie.

The subject is treated more technically, with reference to the coalfields of Northern France, by Mr. W. Topley.* A brief sketch is given of the history of the subject, and also a description of the various borings and the geological structure of the whole district. Coal has already been found in the Weald in Sussex, but it is a lignite of recent formation.

A comparison of the coalfields of the West of England with those of the North of France and Belgium gives indications of what would probably be the state of things in the South-East of England. Coal will probably be found in detached basins, each separated from its neighbour on the east and west by older rocks. It will also probably be much disturbed and faulted, as is the case in the Bristol coalfield, and (but to a far greater extent) in the North of France. Oblique faults have thrust the rock from south to north, so that older beds rest upon newer beds. In the North of France large areas of coal are worked beneath the carboniferous limestone and Devonian rocks. The French coalfields contain a large number of seams, the same colliery often yielding all varieties of coal. Water, both in sinking and in working, is often a source of much trouble and expense in the North of France. Reasons are given for believing that this would not be the case in the South-East of England. The author shows how rapidly the coalfields of the North of France have been developed. Coal has been worked to a small extent in the Boulonnais for 200 years; but in the eastern part of the Pas de Calais coal was only discovered in 1846. The yield of this department now equals one-third of the total production, and one-fourth of the total consumption of France.

In conclusion, the author notes certain localities where explorations might well be carried out in the first instance—places where geologically low beds are brought to the surface being especially suitable. At Chatham Dockyard a boring is already 965 feet deep, and this could be carried much deeper at a comparatively small cost.

The South Yorkshire Coalfield.—The geology of the southern portion of the Yorkshire coalfield is described by Mr. R. Russell,† with especial reference to the coal-bearing strata in the neighbourhood of Sheffield and Barnsley. A general section of the strata is first

* Paper read before the Federated Institution of Mining Engineers, April 30, 1890.

† *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 101-121.

given, and then the author proceeds to deal in detail with the various beds and localities, giving a large number of sections to illustrate the structure of the country and the occurrence of the coal.

The North Staffordshire Coalfield.—J. Ward* deals with the geological features of the North Staffordshire coalfields, and discusses the probability of the occurrence of coal beyond the present limits of the Pottery coalfield. A general description of this district is given, and then the various divisions are dealt with in detail, and sections of the strata are given. A considerable portion of the paper is devoted to the palæontology of the district, and a systematic catalogue is given of the fossil remains of this field.

Coal Mines on the Lower Danube.—According to J. Muntenu,† both coal and lignite occur in the Danubian countries. The former is chiefly of Liassic age. The coalfields of Secul and Eibenthal, in the Banat, are, however, of Carboniferous age. The coal deposits of the Banat at Reschitza and Steierdorf, and of Transylvania, are well known. The author therefore confines his attention to the more important deposits in the Balkan provinces.

The lignite seams belong to the Cretaceous, the Eocene, and the Neogene formations. They are but little worked on account of the unsatisfactory conditions of mining enterprise.

Coal in Western Canada.—In Western Canada, according to W. H. Merritt,‡ coal-bearing rocks are found in three zones. In the plains to the east of the Rocky Mountains and in the eastern flanking ranges, coal occurs in the Cretaceous formation (including the Laramie). In the interior plateau of British Columbia coal is found in the Tertiary formation. On the coast of British Columbia Cretaceous and Tertiary rocks carry coal, and on the Island of Vancouver the Nanaimo coal occurs in the first-named formation. The coals vary from lignite to higher grades, according to the pressure to which they have been subjected. The intensity of pressure is shown by the disturbance, and in many cases is directly in proportion to the distance from the mountain ranges, and does not appear to depend on the weight of superincumbent strata.

* *Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers*, February 1890.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. No. 3.

‡ *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

In the first zone an enormous amount of coal occurs between the western borders of Manitoba and the Rocky Mountains. In the plains the deposits are all lignites, which change to a bituminous coking coal at the seven-foot seam in the Bow River mines, and then to anthracite in the Cascade Valley. The following assays, passing from east to west, convey some idea of the types of these coals:—

	a.	b.	c.	d.	e.
Water	20.54	10.35	6.50	4.41	0.71
Volatile combustible matter . .	33.26	34.40	38.04	40.32	10.79
Fixed carbon	41.15	39.61	47.91	48.27	80.93
Ash	5.05	15.64	7.55	7.00	7.57
Totals	100.00	100.00	100.00	100.00	100.00
Approximate distance in miles } from mountains }	234	128	36	28	0

a. Medicine Hat; b. Crowfoot; c. Galt; d. Bow River; e. Cascade Valley.

At present lignite and coal have only been found in a few places in the interior plateau. At Princetown (a) or Allison's some 20 feet of alternating lignite and shale is found. That at Hat Creek (b) is of better quality, and seams of about a foot thick, giving a fair bituminous coal, exist at Kamloops (c). A good coking bituminous seam of 5 feet thickness is exposed in the Nicola valley (d).

	a.	b.	c.	d.
Water	15.75	8.60	6.26	36.065
Volatile combustible matter . .	35.40	35.51	39.97	
Fixed carbon	41.45	46.84	48.22	
Ash	7.40	9.05	5.55	2.645
Totals	100.00	100.00	100.00	100.00

On the Pacific coast zone only a small amount of coal and lignite has as yet been found. A somewhat dirty two-foot seam has been opened at the base of the Sumas Mountain, and gives on assay:—

Water.	Volatile Combustible Matter.	Fixed Carbon.	Ash.	Total.
4.62	35.68	42.00	17.70	100.00

British Columbia Coals.—Dr. G. M. Dawson* gives, amongst others, the following assays of coal from various portions of the Province of British Columbia:—

* *Report of the Canadian Geological Survey for the year 1887-88 (1889), i. p. 95.*

Locality.	Hygroscopic Water.	Volatile Combustible Matter.	Fixed Carbon.	Ash.
Queen Charlotte Islands . . .	1·60	6·55	83·09	6·76
Yakoun River, Queen Charlotte Islands . . .	2·65	30·59	61·33	5·43
Cool Harbour, Quatsino Sound . . .	1·05	34·38	54·01	10·56
Suquash, Vancouver Island . . .	5·03	41·51	46·52	6·94
Trent River, Comox . . .	0·97	25·09	66·42	5·95
Nanaimo . . .	2·75	30·95	59·72	6·58
Crow Nest Pass . . .	2·10	44·41	43·63	9·86
Watsonkwa River . . .	0·85	39·67	57·51	1·97
The Cañon, Peace River . . .	2·10	21·54	71·63	4·73
Coldwater River . . .	4·45	29·68	57·16	8·71
Upper Nechace, Fort Fraser . . .	10·46	35·01	49·61	4·89
North Thompson River . . .	2·84	33·56	52·03	11·57
Lewes River, Yukon District . . .	6·03	36·92	49·03	8·02

The four last-mentioned are from the Tertiary or Laramie horizon, the others from the Cretaceous.

New South Wales Coals.—The following are results of assays of coals published in the official reports of the Department of Mines of New South Wales :—

Locality.	Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.	Coke.	Sulphur.
Congola . . .	0·05	32·10	52·40	15·45	67·8	1·08
Catherine Hill Bay . . .	3·05	19·95	59·10	17·90	77·0	0·28
Dapto . . .	2·89	16·60	58·20	22·31	...	1·58
Gunnedah . . .	3·00	29·50	58·80	8·70	67·5	0·61
Gunnedah . . .	1·75	14·75	76·76	6·74	83·5	0·64
Gunnedah . . .	3·10	39·60	48·23	9·07	57·3	0·78
Lake Macquarie . . .	0·98	37·72	55·14	6·16	61·3	0·48
Mount Westmacott . . .	0·40	18·91	66·99	13·70	80·7	0·48
Maitland . . .	2·35	40·79	52·76	4·10	56·9	0·84
West Maitland . . .	2·21	36·45	51·51	9·83	61·3	0·68
Western District . . .	3·40	30·60	55·17	10·83	...	0·76
Branxton . . .	2·35	39·62	48·30	9·73	58·0	0·82
Camberwell . . .	2·71	36·09	57·59	3·61	61·2	0·75
Deep Creek . . .	1·52	46·38	40·15	11·95	52·1	8·82
Dubbo . . .	3·60	23·05	54·65	18·70	...	0·58
Grafton . . .	0·56	33·34	43·80	22·30	66·1	0·37
Jamberoo . . .	2·05	24·12	61·96	11·87	73·8	...
Joadja Creek . . .	2·17	30·88	56·13	11·52	67·6	0·66
Lismore . . .	1·01	13·50	71·84	13·65	85·5	...
Mittagong . . .	1·60	29·08	58·80	10·62	69·4	0·45
Moss Vale . . .	3·38	19·84	57·76	19·02	...	0·70
Wallerawang . . .	4·52	24·88	50·45	20·15	...	0·98
Wallerawang . . .	2·58	35·99	53·30	8·13	61·4	1·07

The specific gravity varied between 1·24 and 1·66, this latter being in the case of a coal containing 40 per cent. of ash.

Queensland Coals.—In a recent official report, W. H. Rands, assistant geologist to the Queensland Government, gives the following assay results of Jurassic coals from the Albert-and-Logan district, Queensland:—

No.	Moisture.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.
1.	2·2	22·8	51·0	24·0
2.	1·3	19·7	47·4	31·6
3.	8·1	38·7	50·7	2·5
4.	4·3	13·5	71·1	11·1
5.	8·0	34·0	33·0	25·2

Nos. 1 and 2 gave a compact coke, but Nos. 3, 4, and 5 were non-caking coals.

Coal in Victoria.—R. A. F. Murray* has reported on the coal-seam which was discovered some time back in Jumbunna East. The existence of this seam, which is described as being 4 feet 6 inches in thickness, was unsuspected until it was accidentally discovered by an outcrop in a gully, although the land had been cleared and sown with grass for some years. The quality of the coal appears to be very good. Assay yielded—

Water.	Volatile Matter.	Fixed Carbon.	Ash.
3·92	32·23	60·30	3·55

It is a dense black coal, which cokes well, and is suitable for household and steam purposes.

Mr. Murray† also reports the discovery of coal at Stockyard Creek, near Foster. The seams, which were discovered by trenching, vary greatly in thickness along the tunnel that has since been driven for the purpose of working them. In some places the coal is restricted to a mere strip, whilst at other parts of the tunnel it widens out to 34 inches. The coal is a good coke variety, but of a tender and friable nature. If traced into a continuous seam averaging 3 feet in thickness, it will undoubtedly be found remuneratively workable.

* Reports of the Mining Registrars for the quarter ended December 31, 1889. Melbourne, 1890, p. 65.

† *Ibid.*, p. 68.

J. Stirling* reports on the brown coal deposits at the Latrobe River, where they are mined by the Great Morwell Coal-Mining Company. There can be no doubt as to the extent and as to the phenomenal thickness of the lignite deposits of Western Gippsland. The Morwell brown coal overlies the Mesozoic sandstones. On assay it yielded the following percentages :—

Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
12.30	37.42	49.41	0.87	trace

The discovery of a seam of coal at Boolarra, Gippsland, is regarded by the Government geologist as of considerable importance. In May 1888 the department put a bore-hole down in the direction of the dip of the seam on the banks of Berry's Creek at Mirboo North. In No. 1 bore three feet of coal was passed through between 400 and 500 feet, and a 4-foot seam at 900 feet. Four other bore-holes were subsequently put down, but the seams passed through were very thin when compared with those in No. 1 bore. The drill was then removed farther north, and the seam referred to was discovered at 700 feet. The coal is of good quality, and the Government geologist is of opinion that it is identical with the first seam found in No. 1 bore. He recommends that the bore-hole be continued down another 500 or 600 feet, so as to find out whether it will reach the second seam, corresponding to the 4-foot seam passed through at 900 feet in the No. 1 bore-hole.

South African Coalfields.—A report by W. Galloway† on the coal deposits in the Indwe basin and Stormberg range of mountains has recently been published. It deals with the extent of the deposits, the quality of the coal, and the best means of working it, and gives an estimate of its value. The coalfield covers a fairly symmetrical area, embracing parts of Cape Colony, Orange Free State, Transvaal, Natal, and the whole of Basutoland. The greatest length and breadth are 500 and 200 miles respectively, and the area is about 56,000 square miles. Coal has only been worked in the extreme edges, at distances far apart, in the Stormberg Range, near Molteno, at Indwe, in Natal, and in the Transvaal. The coal measures are approximately a thousand feet in thickness, and the ground is traversed by dykes and horizontal sheets of dolerite. Three districts

* Reports of the Mining Registrars for the quarter ended December 31, 1889. Melbourne, 1890, p. 72.

† *Report on the Coal Deposits in the Indwe Basin and Stormberg Range of Mountains*, pp. 51, and five plates.

were examined. Five seams, ranging from 18 to 27 inches, are described as occurring in Gubenxa Tsomo. The most important seam, however, the Indwe seam, is worked in the Indwe district. The coal has been exposed and worked at seventeen points, where it ranges from 5 feet 7 inches to 1 foot 8 inches in thickness. Numerous thin bands of coal and shale are intermixed, and the whole field is cut up by dolerite dykes. The seam dips 1° to 2° south. At the Indwe mine the workings are 6 feet 10 inches high, with 3 feet 8 inches of good coal and $8\frac{1}{2}$ inches of inferior coal. Four acres, producing 5080 tons per acre, are worked by a kind of long-wall system. The seam is undercut in the shale, and the bottom and top coals are blasted. The roof is sandstone, and there is but little water. Assuming an average thickness of $3\frac{3}{4}$ feet, and a specific gravity of 1.4, an available quantity of 4000 tons per acre gives 302,000,000 tons over the 118 square miles. The following assays and ultimate analysis are by Dr. Hahn:—

	Thickness.	Specific Gravity.	Volatile Matter.	Coke.	Ash.
	Inches.				
Top Seam . . .	11	1.26	19.57	80.43	11.08
Middle Seam . . .	25	1.48	15.32	86.68	28.87
Bottom Seam . . .	11	1.46	17.13	82.87	24.65

C.	H.	N.	S.	O.	Ash.	Coke.
61.021	3.208	2.19	0.434	2.178	30.32	75.26

The cost of the coal is then dealt with, and it is shown that it cannot compete with Welsh coal at Cape Town. Calorifically one ton of Welsh coal equals $1\frac{1}{2}$ ton of Indwe coal, and on an average the latter evaporates 5.62 times its weight of water in a locomotive. The author then proceeds to deal with the question of mining the coal. Fire-damp is unlikely to be present, and the seam can be worked and drained through adits or shafts 500 to 600 feet deep. The method of working, ventilating, hauling, and cleaning the coal is fully discussed, and the labour and cost of plant are also treated.

The Stormberg seam lies on the same horizon, but is thinner and inferior to the Indwe seam. It dips about 3° to the north-east. Six small mines are being worked in this seam, which varies between 2 and $2\frac{1}{2}$ feet approximately. The available quantity of coal may be reckoned at 3000 tons per acre over an area of 10 square miles, giving 19,000,000

tons. A subaqueous lacustrine origin is ascribed to the South African coal.

According to M. Stephens,* the discovery of the South African coalfields dates back only about sixteen years. A report on an outcrop in the Stormberg Mountains was made in 1878, and from more recent information there appears to be sufficient coal which can be made available to last the existing railway system for three hundred years. The eastern railway system is supplied from two mines, the Molteno and the Cyphergate, in the Stormberg district. Most of the coal is obtained from the latter mine, which gives a bituminous and gaseous coal, containing, however, about 29 per cent. of ash, so that the grates have to be kept clear from the resulting clinker. The author then proceeds to discuss the use of this coal for locomotives, and describes Mr. J. D. Tilney's grate with movable bars. Mr. Galloway said that as yet no attempts had been made to wash the coal, large coal being at present exclusively used. No trials of the coking quality have been made.

The African coalfields are also described by A. R. Sawyer.† In the Transvaal and Orange Free State there is a group of small collieries at Boksburg, apparently on an outlier. One seam of coal is being worked at a depth, owing partly to the difference of surface of level, of from 35 to 100 feet. The coal, with thin bands of shale, is 14 feet thick, but only $6\frac{1}{2}$ feet of it is being worked, the remainder forming the roof, and being considered inferior. The carboniferous deposit rests immediately upon the auriferous formation, and it is not unlikely that coal and gold might ultimately be wound up the same shaft. A pillar-and-stall system of work is employed. At Brackpan Colliery, a few miles east of Boksburg, the seam, which is 22 feet thick, was struck at a depth of 85 feet. The seam is nearly level. It has a shale roof 11 feet thick, and a hard floor. Only the lower portion of the seam, 8 feet thick, is being worked, the upper 14 feet, not being of quite such good quality, being left, to form a strong roof. The coal is dull-looking, containing thin bright layers, and but little pyrites. There is no cleat visible. The cost of working is high, but could be reduced to 8s. per ton. At Witklip, east of Brackpan, a bore-hole has been sunk to a depth of 76 feet, where true coal 14 feet thick, getting better downwards, has been met with. The bore-hole was placed

* *Institute of Mechanical Engineers' Proceedings*, January 30. *Industries*, vol. viii. p. 122.

† *North Staffordshire Institute of Mining and Mechanical Engineers*, December 9, 1889.

within an area of 400 acres, which is circumscribed by quartzite, sandstone, and crystalline quartz, which dip under this area. Mr. Sawyer supplies a plan of the locality of the Bedworth Colliery, showing the pits sunk there. He also describes the rocks, and the position, thickness, and quality of the several seams of coal, and gives sections of the strata at both the old and the new pits. The old shaft is 5 feet in diameter, and not bricked. The second opening is an inclined tunnel, the mouth of which was very near the high-water mark of last February. With an output of 1200 tons per day during 300 days in a year, No. 3 seam should last ninety-seven years. With an output of 800 tons a day during 300 days a year, No. 2 seam should last ninety-two years. The present output, which is entirely out of the old pit, is 200 tons per week. It is possible that other seams may be found below No. 3 seam within the basin, which will be still better in quality, while there is also coal outside the basin area. Good fireclay is found at the old pit, but not at the new one. The south-east portion of this coalfield is situated in Natal, where, as in the Cape Colony, the coal-measures are frequently surmounted by a bed of basalt, which, however, does not destroy the horizontality of the measures. With the construction of the railway to the Transvaal frontier, collieries are being opened out. There are some at work near Newcastle, and one near Dundee, the latter of which is being connected with the main line by a branch line eight miles in length. A seam of good coal is being worked at Dundee at a depth of 40 feet from the surface. This colliery is being developed on a large and systematic scale. A seam of $3\frac{1}{2}$ feet in thickness, containing a 6-inch parting, is being worked at Glandslaagte, south of the Biggarsberg, at a depth of from 25 to 40 feet from the surface.

Lakadong Coalfield, India.—A report on the Lakadong coalfield, Jaintia Hills, by T. D. La Touche,* has recently been published. The coal occurs near the top of several small plateaux, and lies above thick beds of nummulitic limestone. It crops out at 10 to 20 feet below the tops of the hills, and has a small dip to the south-east, so that coal could easily be won by shallow pits or by driving in on the outcrop. The largest plateau is called Umlotodo, and has an area of over eleven and a half million square feet, which would give 853,000 tons of coal if the average thickness is taken at two feet. Details of twelve visible outcrops are given. At some of these places, workings have

* *Records of the Geological Survey of India*, vol. xxiii. pp. 14-17, with two maps.

been carried on to a small extent. The roof is hard gritty sandstone, which stands well at first, but becomes soft on exposure to air. The thickness of the coal varies from two up to ten feet and it appears to occur in lenticular beds. The Umat plateau is separated from the one above mentioned by a deep ravine. At present there is only one visible outcrop of a seam four feet thick and 25 feet below the surface. The total yield may be calculated at 311,000 tons of coal. Other small plateaux in the vicinity also contain coal. The coal has not been assayed, but it appears to be similar to the coal at Cherra, and to belong to the Nummulitic or Lower Eocene division of the Tertiary formation.

The Chocktaw Coalfield.—The largest and best coalfields in Indian territory, according to H. M. Chance,* are found in Chocktaw County, and are continuous with the Arkansas deposits, though the coals are of different character. Coal was first mined about sixteen years ago, and the output has steadily increased since 1878. The best coal is found at M'Alester. Coal has been or is being worked at Lehigh, Savanna, and Bryan. The first-named coal gave on assay:—

Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
1·7-1·8	37-40	51-54	0·7-1·0	5-8

The dip varies between 4° and 14°, and the coal is worked on the bord-and-pillar system. Unsuccessful attempts have been made to use the long-wall system. The coal is hard and tough; it is undercut for two feet, and blasted down for three or four feet. It ranges from 3½ feet up to 4 feet 2 inches, without persistent partings. Excellent coke is obtained from the slack. The Lehigh district coal has a high percentage of sulphur, and clinkers badly. The coal-measures are over 5000 feet thick. The author has found three beds exceeding 3½ feet thick, two above 2½ feet, possibly three above two feet and several below this thickness. An assay of the lowest thick bed gave:—

Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
1·80	40·34	51·64	1·33	4·89

The coal is a true bituminous coal, while the Arkansas coals are soft, friable, and non-coking.

* *The Engineering and Mining Journal*, vol. xlviii. pp. 494-495.

Coal in West Virginia.—Professor I. C. White* describes the Roaring Creek coalfield in West Virginia. The field has a basin shape and contains three seams, of which the “Davis” seam or lower Kittanning coal has not yet been developed. The Masontown and Upper Freeport beds have a total thickness of ten feet. The former bed gives a good domestic fuel, and the estimated quantity of coal is 20,000,000 tons. The Upper Freeport seam is calculated to contain 30,000,000 tons above drainage level, and has an average thickness of seven feet. It yields a good coking coal, and does not contain an injurious amount of sulphur.

Coal at Middlesborough, Kentucky.—An assay of coke from Middlesborough, Kentucky, is given by C. R. Boyd,† the results being as follows :—

Fixed Carbon.	Ash.	Sulphur.
93·27	6·31	0·981

The coke is very hard. Eleven to thirteen workable seams are found in this district, varying from 15 inches to 8 feet in thickness. A section of the district is given.

Cannel Coal in the Southern United States.—According to Mr. G. Macfarlane,‡ the best American cannel coal is found in Eastern Kentucky. There is also a large production of inferior cannel in Ohio, Indiana, and Missouri. The following table shows particulars of the different kinds at present produced :—

	I.	II.	III.	IV.	V.	VI.
Thickness of seam, inches	0-30	15-20	16-36	...	0-36	0-36
Volatile matter . . .	60·90	66·30	...	40·20	43·10	49·86
Coke	39·10	33·70	...	59·80	56·90	50·15
Sulphur	1·89	1·32	...	0·956	1·162	0·748
Ash	12·10	4·80	...	8·806	7·40	15·12
Annual production, tons .	15,000	12,000	12,000	12,000	20,000	12,000

I. The “Breckinridge,” Hancock County, Western Kentucky. II. “Grayson” or “Old Kentucky Boghead,” Carter County, Kentucky. III. “Chattaroi,” Johnson County, Eastern Kentucky. IV. “White-

* *American Manufacturer*, vol. xlv. No. 5.

† *The Engineering and Mining Journal*, vol. xlix. pp. 171-173.

‡ *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

house," Johnson County, Kentucky. V. "Cannelton," Kanawha County, West Virginia. VI. Jellico, Campbell County, Tennessee.

Coal in San Salvador.—Coal is being worked at four collieries in the State of San Salvador, South America. The Titequapa coal is of 1·57 specific gravity, and contains 10·5 per cent. of ash. There are also several deposits of lignite, and nine hæmatite mines are being worked.*

Coal in the Argentine Republic.—H. D. Hoskold† describes the geology of the Argentine Republic, with the view of finding some clue for the location of coal-bearing strata. Carboniferous fossils have been found in the island of Oso, and in other places. Jurassic and Silurian formations are found in contact in certain situations, and the general formation of the country leads to the supposition that the intermediate beds may still exist in places, as they do in Brazil. Bituminous schists with badly preserved fossils have been found around the town of Mendoza. Coal has also been discovered to the south of this town, containing 68 per cent. of carbon, 6 per cent. of hydrogen, 16 per cent. of oxygen and nitrogen, and 9 per cent. of ash. Eight beds were found in a section about 330 yards long, and varying from 3 inches to 3½ feet in thickness, and also two beds of bituminous sandstone. Since 1856 the existence of coal in Marayes, province of San Juan, has been known. An assay in 1871 showed 46 per cent. of coke, 10 per cent. of ash, and 43·96 per cent. of volatile matter, thus classing it as a bituminous lignite. Sections of this field are given by the author. Assays of coals from various provinces are given, the results being as follows:—

Class.	Density.	Water.	Volatile Matter.	Ash.	Coke.	Sulphur.
Paganzo (Rioja) . .	1·582	2·00	30·10	37·00	67·90	0·563
" " " " " "	1·313	8·55	21·45	1·70	67·00	...
San Juan (T.S.K.) . .	1·550	1·50	30·80	24·55	67·70	0·384
Mendoza . . . . .	...	10·50	10·20	35·82	70·30	...
" " " " " "	...	14·05	21·55	20·20	61·40	...
" " " " " "	1·430	12·90	20·65	29·36	66·45	...
Marta Mine	1·420	16·52	32·10	16·36	51·40	0·27
" " " " " "	1·460	23·40	36·20	11·66	40·40	0·40
El Magallanes	1·400	1·40	49·70	33·20	48·90	...
" " " " " "	...	2·75	33·07	11·50	64·18	...

Estimations of cost and profit are also given.

* *Colliery Guardian*, vol. lviii. p. 772.

† *Memoire Général sur les Mines de la République Argentine*. Buenos Aires, 1880, pp. 307–353.

The Utilisation of Coal-Dust.—Successful efforts have been made at the works of the Reading Railway at Mahanoy City, Pennsylvania, to utilise for briquettes the coal-dust obtained in the working of the company's collieries, amounting to about one-seventh of the total output. The coal-dust is mixed with one-tenth its weight of pitch, softened by the aid of steam, and compressed into briquettes under a pressure of 35 tons.*

III.—COKE.

Coking in the Saar District.—According to Remy,† at the present time horizontal coke-ovens with vertical gas-flues are in general use in the Saar district. The only Appolt coke-ovens with vertical chambers still remaining at Altenwald will, when worn out, be replaced by horizontal ovens. Of these, the type most generally used is the François-Rexroth. At Burbach there are eight Coppée ovens, and quite recently the Röchling patent oven, with recovery of by-products, has been adopted. The François-Rexroth coke-ovens give a smaller out-turn of coke and a greater concentration of ash than the Appolt ovens, since in the former the material to be coked is partly burnt. On the other hand, the Appolt coke-ovens are more expensive to erect; the chambers in the centre of the oven work hotter than those at the walls, and thus the coke is not uniform in quality, while the materials of which the oven is built are subjected to irregular wear. The Coppée coke-ovens have not been found suitable for the Saar coal on account of the large proportion of moisture it contains, a proportion amounting to 18 to 20 per cent. Attempts have been made to overcome the difficulties thus caused by a combination of the Coppée and François-Rexroth coke-ovens, in which the air for combustion is introduced and the flues at the base are cooled by cold air passing to and fro as in the Coppée oven, whilst the ovens are broader, and the flue, divided by one longitudinal section, is heated by the gases of the oven itself, and not by those of the adjacent ovens. The burning of the charge at the surface is considerably lessened, and the out-turn is higher than in the ordinary François-Rexroth coke-oven.

At Altenwald, twenty-five of Röchling's coke-ovens (German patent No. 38,312) have been erected, and twenty-five more are in course of construction.

* *Scientific American*, vol. lxi. p. 353.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxvii. p. 11, with drawings of coke-ovens.

1890.—i.

The charge of the coke-oven varies, according to the size, from 2 to 7 tons, the out-turn being 1 to $3\frac{1}{2}$ tons. Per ton of coke produced, 130 to 140 gallons of water are used for quenching.

Kentucky Coke.—J. Fulton* gives the following results of a comparative examination of Connellsville coke and coke made by the Cumberland Valley Colliery Company, Pineville, Kentucky:—

	Connellsville Standard Coke.	Pineville Coke.
Grammes in 1 cubic inch { dry	15·47	14·10
{ wet	23·67	22·24
Pounds in 1 cubic foot { dry	58·98	53·73
{ wet	87·34	84·73
Percentage by volume { coke	49·96	50·37
{ cells	50·04	49·63
Ultimate strength	301·0	227·0
Height of furnace charge supported without crushing	120·0	91·0
Hardness	3·5	3·0
Specific gravity	1·89	1·71
<i>Composition:—</i>		
Fixed carbon	87·46	94·66
Moisture	0·49	1·14
Ash	11·32	3·78
Sulphur	0·69	0·59
Phosphorus	0·029	0·007
Volatile matter	0·011	0·041

IV.—LIQUID FUEL.

Constitution of Petroleum.—J. A. Le Bel† considered that normal paraffins might alone be present in petroleum, the occurrence of the secondary paraffins being due to isomeric change occurring during the manipulation. Experiment, however, proved that other than normal paraffins were present in natural petroleum. This result the author regards as negating the fermentation theory of the formation of petroleum, since no known fermentation simultaneously produces both classes of compounds.

Oil-Fields of India.—B. Redwood‡ in a lengthy paper sum-

* *Iron Age*, vol. xlv. p. 876.

† *Bulletin de la Société Chimique*, vol. ii. pp. 305-307; *Journal of the Chemical Society*, vol. lviii. p. 223.

‡ *Journal of the Society of Chemical Industry*, vol. ix. pp. 350-370, with maps and illustrations.

marises what is known of the petroleum deposits of Burma, Assam, the Punjab, and Baluchistan. The Arakan Islands and Lower Burma are first dealt with, after which a full account is given of the Upper Burma district as described by Dr. Noetling* and others. The character of the oil from various localities is described. A shorter notice is also given of the Assam, Punjab, and Baluchistan districts. Maps and illustrations are appended to the paper. The author arrives at the following conclusions:—Throughout India petroleum occurs in the Tertiary formation in greatly disturbed strata. Petroleum occurs in greatest abundance in the Khátan oil-field in Baluchistan, but the oil is not of satisfactory quality, even as liquid fuel; the locality is comparatively inaccessible, and the climate is bad. The best oil for the refiner is obtained from Arakan, which can be developed more advantageously than the deposits in Upper Burma. Too little is at present known of the Indian oil-fields to admit of prediction as to their future.

Petroleum in Roumania.—The most productive oil-bearing districts of Roumania, according to S. Taubes-Barladu,† are found on the south-east of the Carpathian Mountains. Oil is obtained in five localities. At Ploresti and other places the ground is largely charged with gas. The oil is obtained from shafts and galleries, which are timbered, and from wells which average 165 to 230 feet in depth. Lately, however, the output has been largely increased by deeper borings. The total yield from Walachei amounts to 9000 tons, containing 20 to 23 per cent. of solid paraffins. The oil-fields on the south of the Carpathian Mountains, in the provinces of Prahova, Dimbowitzza, and Buzen, extend to a distance as yet undetermined, but are apparently connected with those of Galicia.

Petroleum in Servia.—The Belgian Minister at Belgrade, in his last report to the Belgian Foreign Office, says that up to the present time no petroleum in a liquid state has been discovered in Servia, but that the country is extremely rich in bituminous schist. It is found in the departments of Pojarevatz, Kniajevatz, Nisch, Alexinatza, Tchoupaia, and Valievo, in situations the details of which are given. Up to the present these deposits have not been worked.‡

* *Journal of the Iron and Steel Institute*, 1889, No. II., p. 352.

† *Zeitschrift für angewandte Chemie*, 1889, pp. 605-606.

‡ *Journal of the Society of Arts*, vol. xxxviii. p. 498.

Oil-Fields of Barren County, Kentucky.—A description of the oil-fields lying in Southern Kentucky and Northern Tennessee is given by M. Fischer.* The first wells driven are known as the Adams group, and were sunk in 1865 in Barren County, Kentucky. Since that time they have produced about twenty barrels daily. Two other groups of wells were sunk about 1887, and have produced gas and oil, both amber and green. Details of the depth and produce of these wells are given.

The surface geology is simple. The northern half of the region is overlain by the St. Louis group, and the Keokuk shales crop out at the south. The thickness and order of the beds is as follows :—

	Feet		Feet
St. Louis	200	Niagara	50
Keokuk	250	Hudson River	800
Black shale	50	Trenton	250

Amber oil is found in the Keokuk, green oil and gas in the Niagara beds. The amber oil is found at a horizon about 400 feet below the green oil, and again at a second horizon some distance below, but in small quantities. The Hudson River rocks consist of alternate layers of shales and limestones, the former being exceedingly rich in organic remains. All factors for the production of oil are found, and the rock is porous, but covered with a thick layer of impervious shale.

Petroleum in the Argentine Republic.—According to H. D. Hoskold,† the provinces of Mendoza, Salta, and Jujuy contain petroleum-bearing rocks. In 1880 boring was commenced in the former province, and the third attempt found a flowing well yielding thirty-five barrels daily, at a depth of 338 feet. The oil is of good quality, but operations do not appear to have been extended.

Tar as Fuel.—At Fagersta, in Sweden, Brinell‡ utilises producer tar by mixing it with charcoal dust. The mixture, when dried, is used for heating boilers. The production of steam is equal to that obtained with the best English coal, but the consumption is greater. The value of this fuel is of course dependent on the proportion of moisture in the tar and in the charcoal. In place of charcoal-dust, sawdust has occasionally been employed, and the fuel obtained is not much inferior to that made with charcoal.

* *The Engineering and Mining Journal*, vol. xlix. pp. 197-198.

† *Mémoire Général sur les Mines de la République Argentine*. Buenos Aires, 1880, pp. 354-367.

‡ *Jernkontorets Annaler*, vol. xlv. pp. 140-160.

The producer of the 7-ton open-hearth furnace at Fagersta yields annually 3461 cubic feet of tar, which, according to the author's calculations, based on comparative experiments with South Yorkshire coal, represents a value of £225.

E. G. Odelstjerna is of opinion that all producers with condensers in Swedish ironworks should be converted into producers without condensers, and advises that buildings should be erected in which the tar fuel may be dried, and that the producers should be provided on one side with grates, and on the opposite side with down-takes for the gas. Only in cases in which the distance between the producer and the furnace is very small can the gas be taken away from the top of the producer, on account of the large amount of soot formed.

Classification of Hydrocarbons.—In an exhaustive paper on bitumen and its compounds, W. P. Blake* proposes the following classification of the hydro-carbons:—

	Gaseous	{ Marsh gas. Natural gas.
	Liquid	{ Naphtha. Petroleum.
	Viscous	{ Maltha. Mineral tar. Brea. Chapapote.
Bituminous	Elastic	{ Elaterite. Wurtzilite.
	Solid { Asphaltite	{ Albertite. Grahamite. Untaite.
		{ Bituminous coal. Semi-bituminous coal. Anthracite.
Resinous		{ Succinite (amber). Copalite. Ambrite, &c.
Cereous		{ Ozokerite. Hatchettite.
Crystalline		{ Fichtelite. Hartite, &c.

V.—NATURAL GAS.

Natural Gas in the Eastern Ontario Peninsula.—The existence of natural gas in the St. Lawrence Valley, between Quebec and

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

Montreal, has been known for many years, but the earliest practical explorations, according to C. A. Ashburner,* were made in 1880 for gas in commercial quantities. In this district the gas was only found in limited reservoirs in the glacial gravel, where the accumulation had resulted from the decomposition of vegetable remains. By gas in commercial quantities, the author means such quantities as will give reasonable profit after allowing for all expenses and the current rate of fuel. It is to be understood that a gas supply is exhaustible just like a bed of coal, for production does not proceed concurrently with the withdrawal, at least in a commercial sense. As a general rule, gas and oil are found together, though one or other may be in very small quantities.

The drift gas between Montreal and Quebec has been worked in many instances, but the operations have proved unprofitable. All the gas which can be successfully utilised comes from the Trenton limestone strata, or from the immediately overlying Utica shales; but the author is of opinion that no great quantities will be found in these formations in this district.

The production of oil and gas in the States of New York and Pennsylvania rendered it possible that gas might be found between the Lakes Ontario and Erie, at a depth not exceeding 1500 feet. Gas was found at Port Colborne at a depth of 760 feet, but the Trenton limestones were not reached at 1500 feet, and it was supposed that this find was really gas from the Trenton strata. A well was sunk at Thorold, and it was also determined to sink in the St. Catherine's district. The strata have a general dip towards the south of 35 feet per mile, with local rolls, which are hardly large enough to be called anticlinals. These systems of rolls may have an important bearing if gas is to be found in any quantity. The St. Catherine well was sunk to a depth of 2200 feet without finding a permanent supply of gas, though several pockets were found in the Medina, Hudson, Utica, and Trenton strata. A general section of this district was compiled from these wells, and is given to show the thicknesses of the various Devonian, Silurian, and Cambrian beds. Mineralogical and chemical examination of bores from the Trenton limestones did not give promise of much gas. The author finally comes to the following conclusions:—Gas in the Buffalo wells comes from lime shales 15 to 60 feet above the base of the Salina formation, and in small quantities from near the top of the

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

Niagara formation. The top of the Trenton limestone should be met at about a depth of 2400 feet near Buffalo. Little hope can be entertained of finding gas in the Trenton limestone under the Eastern Ontario peninsula. In the southern portion of this peninsula gas may be found in favourable localities and in moderate quantity in the following horizons :—from 15 to 75 feet above the bottom of the Salina formation, in parts of the Niagara formation, in the upper part of the Medina sandstone, and in the Hudson River and Utica strata. It cannot be expected that a paying gas stratum will be found unless it is covered with at least 400 feet of strata ; nor can it be expected that gas will be found in two or three strata in the same well.

Natural Gas in Ohio.—A general review of the natural gas and petroleum industry in Ohio during 1889 is given by E. Orton.* The progress has consisted in development and utilisation, but no new sources have been found. The four productive horizons are the Berea grit, the Ohio shale, the Clinton and the Trenton limestones. The Ohio shales only produce gas in small quantities and at low pressure, but the supply is constant, and promises to remain so. Cambridge is the only town that derives its supply from the Berea grit, but this stratum also yields a small amount of gas at the Neff Wells, near East Liverpool, and at Mount Vernon. Considerable search has been made for oil, but without great success, as only several small supplies have been found up to the present.

The Clinton limestone gas supply has been largely developed. Lancaster, Newark, and Columbus have considerably improved their position, and other towns are also drilling. Oil has been reported near Lancaster. The Trenton limestone still holds its own as being the largest producer. During 1889 approximately 9,000,000 barrels of oil have been obtained, and a method has been found of desulphurising the oil. The gas supplies have been largely developed, and several of the largest producing wells have been struck in this year ; but, as a whole, the field has been steadily losing pressure. The first opened portions are visibly near exhaustion, and appear to be drowned out by salt water. It would appear that the natural pressure of the gas is due to the head of water, for in nearly all drowned wells the water stands at a pretty uniform height of 600 feet above sea-level ; and this salt water is always observed to follow the gas. The Trenton limestone crops out on the south shores of Lakes Huron and Superior at about this height

* *American Manufacturer*, vol. xli., No. 4.

above sea-level, so that it is not far to seek for the origin of the pressure. Moreover, the pressure of the gas in the wells in several cases corresponds almost exactly to the pressure calculated from the head of water; and this renders this view of the case a practical certainty. The following tabular statement of the pressures in some of the wells is given:—

Well.	Depth to Gas.	Gas below Sea-Level.	Calculated Pressure.	Observed Pressure.
	Feet.	Feet.	Lbs.	Lbs.
Muncie, Indiana	850	0	286	280-290
Marion, Indiana, Well No. 3	870	78	322	323
St. Henry's, Dwyer Well	1156	200	385	375
Findlay, Pioneer Well	1100	336	448	450
Bloom Township, Kelly Well	1145	395	474	465

The subject of gas pressure is also dealt with in a paper read before the American Geological Society.*

Natural Gas in Cuyahoga County, Ohio.—P. Neff† describes several gas wells in Cuyahoga County, Ohio, which derive their gas from the Sylvania sand. The Cleveland rolling-mill well strikes this stratum at a depth of 1660 feet, and Clinton red limestone at 3050 feet, fully 1000 feet above the Trenton limestone. Another well, $1\frac{1}{4}$ miles south, also penetrates the Sylvania sand at about the same depth, and yields 15,000 to 175,000 cubic feet daily. A third well in the immediate vicinity yields no gas from this stratum, and still another well thirteen miles distant also yields no gas. The general trend of this bed appears to be north-east, at an angle of 46° . From the data derived from these four wells there appears to be no hope of striking a productive region of the Clinton limestone in this district, but the general geology of the country encourages a hope that the Sylvania sand may be found productive in places.

Natural Gas in Western New York.—A map is given in the *American Manufacturer* ‡ showing the distribution of natural gas and salt wells in Western New York.

* *American Journal of Science*, vol. xxxix. pp. 225-229.

† *American Manufacturer*, vol. xlvi., No. 9.

‡ Vol. xlvi., No. 14.

VI.—ARTIFICIAL GAS.

Fuel Gas.—G. W. Goetz* gives some particulars of experiments made by the Fuel Gas and Engineering Company on the production and use of fuel gas. In order to determine the volume of producer gas which could be made from a ton of coal, Pittsburgh coal of the following composition was used :—

Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
1.26	36.22	57.98	0.70	3.78

The producer was cylindrical, with an internal diameter of 6 feet and external height of 20 feet. Cleaning and ash doors were placed opposite each other at the bottom, and the fuel was packed by an annular cast iron rammer, which was operated by a pneumatic cylinder placed above the producer. A positive air blast was used, and steam was admitted under the grate. The consumption was 12 to 15 tons of coal in twenty-four hours. Average production of a ten days' run, corrected for temperature and pressure, was 131,280 cubic feet of purified gas per ton of coal. The average composition of the gas was—

CO ₂ .	CH ₄ .	H.	C ₂ H ₄ .	CO.
3.4	3.1	9.2	0.8	25.3

the remainder being chiefly nitrogen. The carbonic anhydride was sometimes as low as 1.4 per cent., and, with a lower pressure of blast, would not exceed 1 per cent.

The ordinary single-handed puddling furnaces at Pittsburgh consume about 36,000,000 British heat units per ton of pig iron ; whereas, when gas is employed, about 14,000,000 heat units will do the work. It was found that 13,250 cubic feet of natural gas, with 1,100,000 heat units per 1000 cubic feet, would puddle one ton of pig iron ; whereas, by using a gas with nearly 300,000 heat units, 47,000 cubic feet were consumed, or by employing gas with 266,000 heat units, 54,000 cubic feet were used to puddle one ton. In each instance the amount of heat approximated to 14,000,000 units. This result was to be expected, but it has been demonstrated practically by these experiments. Similar results were obtained in evaporation trials.

In connection with this subject W. H. Blauvelt calculates the weights of the carbon and hydrogen which are distributed among the various products, and, from considerations based thereon, urges the

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

following points:—A large percentage of the energy of the coal is lost when the gas is made in the ordinary low producer and cooled to the temperature of the air before being used. To prevent this source of loss, the producer should be placed so as to lose as little as possible of the sensible heat of the gas, and to prevent condensation of the hydrocarbon vapours. A high fuel bed should be carried, keeping the producer cool on top, thereby preventing the breaking down of the hydrocarbons and the deposit of soot, as well as keeping the carbonic anhydride low. A producer should be blown with as much steam mixed with the air as will maintain incandescence. This reduces the percentage of nitrogen and increases the hydrogen, thereby enriching the gas. The temperature of the producer is kept down, thus preventing radiation through the walls, and in a large measure preventing clinkers.

Oil Gas.—In the Sutherland oil gas furnace the oil is drawn into the heating pipes by steam jets, and is caused to circulate through a large number of iron tubes. The pipes are not intensely heated, but the oil is thoroughly gasified by its long travel through the pipes. An auger-shaped device is placed in each pipe to direct the gas to the walls of the pipes, and it can be withdrawn for cleansing purposes. For large production, this apparatus is combined with the Allen-Harris water-gas producer. In this case fire-clay tubes are substituted for the iron tubes, but the auger device is retained. The water gas is generated in double retorts with perforated fire-clay slabs in their bottoms to allow the circulation of superheated steam through the incandescent fuel.*

Oil Gas Producer.—Elevations and sections of the Turner oil gas producer, which has been successfully used at Columbus, Ohio, for reheating furnaces, are given in the *American Manufacturer*.† The retorts and superheaters are heated by a slack fire. The steam is highly superheated by circulation through a number of boxes, and then meets the vaporised oil, with which it passes through the retorts, where the carbon of the oil combines with the oxygen of the water. This product passes to a tar-depositing chamber, and on its passage heats and vaporises the oil. From the tar chamber the gas passes to the gas superheaters, and thence direct to the furnaces. The steam superheaters and retorts are made of iron or steel, and the gas superheater is made of heavy wrought iron pipes.

* *American Manufacturer*, vol. xlv., No. 11, illustration.

† Vol. xlv., No. 1.

A New Gas Producer.—Thwaites' "Simplex" gas generator is illustrated in *Industries*.* The air for combustion is heated by passing it through a jacket which surrounds the producer in its hottest part, and is then further heated by its passage over the cast iron plates which carry the firebars. An internal curtain wall forms one side of the fuel hopper, and causes the volatile hydrocarbons to flow through the incandescent fuel in order to render them more permanent.

Brookes' Gas Producer.—A dimensioned sketch of the Brookes' gas producer is given in the *American Manufacturer*.† It is shaped somewhat like a blast furnace, and the fuel is fed in through a bell and hopper.

Smith's Gas Producer.—The gas producer invented by M. V. Smith ‡ is a modified form of the Siemens producer. The special feature is the placing of two Siemens producers opposite and in juxtaposition to each other, so as to form one double breast producer, having a continuous grate surface extending from one breast to the other. Suitable ashpit-doors are placed under each breast of the producer, and are provided with openings through which a poker can be inserted for breaking up the clinker without interrupting the work. The hoppers are also of special form. A revolving cylinder is supported directly under the mouth of the hopper, and extends the full breadth of the producer. A slot in the cylinder admits coal or discharges it as the cylinder is rotated. The lower part of this device is provided with a water-jacket, and, as gas does not circulate through it, it will not warp. Coal is fed in at both sides of the producer on to walls which incline down towards the centre, and thus the fuel is lower there than at the sides. This reduces the labour necessary for shifting the fuel, and light tools can accordingly be used. The uptakes are placed directly over the grate bars, and extend the full width of the producer. Dust-catchers are placed at the bottom of the cooling tube, and are provided with gravity doors for discharging the dust. At the end of the cooling tube a spray of water plays down the down-take, and the water is removed at the bottom by means of a water seal and trap. Steam is supplied to the grates through pipes which support the firebars, and is superheated by causing it to circulate through pipes which are built into the brickwork setting.

* *American Manufacturer*, vol. viii. pp. 330-331.

† Vol. xlv., No. 2.

‡ Vol. xlv., No. 9, with an illustration.

VII.—*COAL-MINING.*

Average Depth of Coal-Mines.—Professor E. Hull* has endeavoured to form an estimate of the probable average depth at which coal is now being worked in the British Isles. Full data cannot be obtained of the depths of all collieries now at work, nor of their output from various seams. Shallow pits in general have a smaller output than deep pits. Before the introduction of the steam-engine, the average depth did not exceed 100 yards, whilst a near approximation for the present time would be 350 to 400 yards. This would give an annual increase of $4\frac{1}{2}$ yards; but it was smaller than this at first, and greater in recent years. Mr. J. T. Boot has furnished some details of the Yorkshire, Derbyshire, and Nottinghamshire coalfields, from which the following table is compiled :—

Depth between	Yards.		No. of Collieries.
	0 and 50		
" "	50	100	8
" "	100	150	14
" "	150	200	31
" "	200	250	21
" "	250	300	14
" "	300	350	10
" "	350	400	8
" "	400	450	2
" "	450	500	2
" "	500	550	5
" "	550	600	4
" "	600	700	1

Some of the shallower pits are not at work, and so it may be assumed that an average of 250 yards may be taken for this field. The Lancashire and Cheshire workings are probably much deeper, but South Wales, Staffordshire, Newcastle, and Central Scotland also produce their maximum output from the same average depth of 250 yards.

Coal-Mining at Warora.—The Warora colliery, worked by the Government, lies almost in the centre of India, $20^{\circ} 45'$ north latitude, and $79^{\circ} 5'$ east longitude, near the northern limit of the Wardha or Chanda coalfield. Full details of this mine and the neighbourhood are given by C. Z. Bunning.†

* *Transactions of the Manchester Geological Society*, vol. xx. pp. 417–425.

† *Transactions of the North of England Institute of Mining and Mechanical Engineers*, vol. xxxviii. pp. 77–169, with map.

This coalfield lies in the northern division of the Gondwana system, the coal-bearing rocks of India. To the north-east, the overlying Deccan trap covers the formation; to the north-west, metamorphic rocks are found; and the Lower Windhyan shales and limestones form the south-west boundary. The system appears to range from the Permian to the Upper Jurassic, and so is of later origin than the carboniferous strata of Europe. The Wardha coalfield lies in the Barakar group of the Lower Gondwana system; below are the Talchirs, and above are the Kamphthis rocks, which lie unconformably on the Barakars. The Talchirs consist of silty shales and sandstones, and have not been found exceeding 800 feet in thickness. The Barakar beds in this field are 250 feet thick; in Bengal they reach 3300 feet. In descending order they contain three seams of coal, sandstones, and shales, a few thin carbonaceous beds, and sandstones and shales again. According to Mr. Hughes, the coalfields of this district may be summarised as follows:—

	Actual Quantity.	Amount Available.	Square Miles.
	Tons.	Tons.	
Warora basin	20,000,000	14,000,000	$\frac{3}{4}$
Ghugus	90,000,000	45,000,000	3
Wun	2,100,000,000	1,500,000,000	80
Between Wun and Papur	105,000,000	50,000,000	11
Between Junara and Chicholi	150,000,000	75,000,000	5 to 6
Sarti and Paoni basins	60,000,000	30,000,000	1
	2,525,000,000	1,714,000,000	101 $\frac{3}{4}$

These coal-basins extend over 11,000 square miles, almost one-third the total area of coalfields in India.

Warora lies in an extensive plain in the valley of the river Wardha. Coal was first found at this locality in 1831, but active operations were only begun in 1870. The coal occurs at depths varying from 100 to 300 feet, in three seams, of which the first does not extend over the whole area, and is hardly true coal, as it consists of a soft black shale. About 14 feet below, the second seam is found, varying from 14 to 17 feet in thickness. This seam is really shale with thin streaks of true coal interspersed. Below this is 4 $\frac{1}{2}$ to 7 feet of shaly sandstone, and then the third seam, of the same average thickness as No. 2. Immediately beneath is a hard white micaceous sandstone with a few thin seams of coal. Assays of No. 2 seam gave—

Fixed carbon.	. . .	42.08	45.4	57.0	48.0	43.42	45.6	35.5
Combustible volatile matter.		37.85	26.5	28.5	38.0	31.64	26.0	26.4
Water	. . .	...	13.9	...	...	11.00	14.0	13.0
Ash	. . .	18.20	14.2	14.5	14.0	13.94	14.4	24.0
Sulphur	. . .	1.87	2.85	...	...	1.15	...	...

The first sample given above was washed in a streamer 100 yards long with a good body of water. The washed coal yielded—

Fixed Carbon.	Volatile Matter.	Sulphur.	Ash.
46.91	36.65	0.74	15.70

and the dirt gave—

Carbonaceous Matter.	Insoluble Earthy Matter.	Iron.	Sulphur.
15.00	18.20	22.61	24.08

Washing removes a large part of the sulphur, but not the ash. Attempts to coke the coal have been absolute failures. Even when mixed with a large proportion of coking coal and pitch, the coke was very poor. Coal from No. 3 seam gives on assay—

Fixed carbon	. . .	41.32	39.10	40.16
Combustible volatile matter	. . .	25.31	25.65	30.05
Water	. . .	11.99	10.54	14.65
Ash	. . .	19.70	23.85	14.26
Sulphur	. . .	1.68	0.86	0.88

The sulphur is chiefly present as pyrites, and the ash and moisture are very high. The coal might be improved by hand-picking, but the cost would be much increased. The coal is very friable, and speedily weathers into small prismatic fragments. Attempts have been made to utilise the small coal for making patent brick fuel, but without success. There is a distinct cleavage at right angles to the strike, and the coal also tends to split up in horizontal lines. It is mined most easily in the direction of the cleat, so the bords are driven in the direction of the strike and the headways at right angles. The coal is tough and woody in its bed, and so is difficult to mine. The calorific power of the coal is 7.7.

Spontaneous combustion readily occurs in this coal, so that several extensive fires have taken place where the goaf has been packed with small coal. At the present time three areas, extending over some forty-two acres, are either hot or on fire. Great difficulty is experienced in stopping off these dangerous places, as the roof is very bad. No fire-damp is found in the mine, but the fumes from the hot or burning

coal require removal by careful ventilation, which is also necessary to cool suspected areas. A Waddle fan was erected in 1887, and gives excellent results, as the seams are large and there are five downcast pits. The ventilation is well arranged with twelve splits, air-crossings, &c.

Above-ground the gear is of ordinary type. The coal is screened over bars one inch apart, and superficially picked by women. The pumping-engines are in bad repair, and should be replaced by one capable of dealing with 800 gallons a minute. The coal-waggons are built of iron and steel with spring buffers, and carry 10 tons; they are loaded at the rate of a penny per ton.

Under-ground the coal is worked by a contractor, who supplies the haulage work and necessities. Work is carried on in three eight-hour shifts. Open lights are used. The speed of driving is very slow, and each man only produces 2·8 to 4·1 tons per week, according to the nature of the work, so that a large output is practically impossible. At present the pillars are worked 60 feet square, with 12-feet bords and 7-feet headways. The coal is kirved to a depth of 3 feet, and brought down by blasting, which is done by a special shotman. All the coal is trammed by hand, though bullocks have been tried with some success. The long-wall system has been tried, but appears impracticable, owing to the fear of spontaneous combustion.

Timber is very expensive, so but little timbering is used. Coal is left to form the roof. This causes a great loss, but the natural roof weathers so badly that it must be done.

The total output at Warora since the commencement in 1875 up to 1888 has been 935,517 tons, and has risen steadily, with the exception of the years 1879 to 1881, up to a production of 134,236 tons in 1888.

Very full details are given of the cost of boring, sinking, and working the coal, and the cost of the plant. The labour question is also fully dealt with.

The Brandeis-Kladno Colliery in Bohemia.—The coal measures at Brandeis-Kladno rest on Silurian slates, and are overlain by beds of the New Red Sandstone. The main seam is 6 to 12 yards in thickness, and dips 6° to 15° to the east.* In this coalfield, the Austrian State Railway Company possesses a series of collieries, with seven shafts in operation, the output in 1887 having amounted to 663,000 tons of coal. The shafts are 850 to 1350 feet in depth. The Thinnfeld shaft

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. pp. 49-51, 68-71.

reached the main seam at a depth of 970 feet in 1854. The Kübeck shaft reached it at a depth of 1150 feet four years later. In both cases the seam is 33 feet thick, and of excellent quality. Since 1858 five other shafts have been sunk by the company. These are as follows:—

Name.	Reached Coal at Depth of	Thickness of Seam.	Annual Output.
	Feet.	Feet.	Tons.
1. Pruson	852	18	38,000 to 40,000
2. Bresson	930	24½	140,000 to 145,000
3. Engerth	1230	24½	140,000
4. Barré	970	...	150,000
5. Hnidusch	1240	...	exploratory

The Pruson and Hnidusch shafts are of brick, and circular in section, 11½ feet and 14 feet in internal diameter respectively, whilst the others are timbered and rectangular in section, 15 to 20½ feet long by 5¾ to 7 feet broad. The Pruson shaft is divided into two unequal sections, the larger being used for winding, and the smaller for pumping and ventilation. The Hnidusch shaft is divided into four sections, and the rectangular shafts are divided into three or four sections. The coal is worked by the pillar-and-stall method, with self-acting inclines. About 450 coal-getters are usually employed, the output per shift per miner amounting to three tons of coal. For every ton of coal wrought, the consumption of mine-timber did not exceed 0·007 cubic foot. The total length of levels open amounts to 37 miles. The main roads have double lines of rails, the gauge being 28 inches. The trucks are of strong sheet-iron; they weigh 550 lbs., and hold 12 cwt. of coal. The haulage at the face is effected by men, and in the main roads by horses, of which fifty to sixty are employed.

The pit-bank is lighted by electricity, arc lamps being used. From 1855 to 1887 the output from all the shafts amounted to 12,819,900 tons. At the Kübeck shaft a 450 horse-power Cornish pumping-engine is used, and excellent pumping machinery is provided at the other shafts. At the Thinnfeld shaft the ventilation is effected by a Lemielle fan driven by an 80 horse-power engine. At the Pruson shaft there is a Rittinger fan; at the Bresson and Engerth shafts Guibal fans, 27½ feet in diameter; and at the Barré shaft a Pelzer fan.

The total motive-power at these collieries represents 3750 horse-power, which is distributed as follows:—

	Horse-Power.
Winding	1020
Underground haulage	30
Chain haulage	8
Pumping	2146
Ventilation	260
Coal-sorting	48

The remainder is used for driving the smaller machines, such as feed-pumps, lifts, &c. For the production of steam there are seventy boilers of various types.

At these collieries 3000 workmen are employed. Of these, 1900 work underground, and 200 attend to the engines and boilers.

The Cost of Deep Borings.—Professor F. von Rziha* publishes a list of fourteen deep boreholes, showing their depth and the cost of sinking, together with the character of the rock. The average depth given is 1833 feet, and the average cost per foot is £2, 5s. 6d., the minimum cost being about 15s. 3d., and the maximum about £5, 2s.

The Prevention of Overwinding.—Mr. A. Bertram† compares the various forms of safety apparatus, and describes a device for preventing overwinding. Safety cages are often dispensed with where they were formerly used, owing probably to their intricacy, or liability to act when they were not wanted. Besides this, they do not safeguard the cage in case of overwinding, and they are not very suitable for wire guides. Safety or detaching hooks are sometimes self-suspending; others merely release the cage, which is held by catches on the headgear. They are undoubtedly of great use, especially in the case of slow overwinding, but where this is fast, the whole of the gear is liable to be torn away. Stopping gears may be divided into two classes, the first of which shuts off steam and applies the brakes directly the cage has been drawn too high into the headgear; the second contemplates automatic winding. Those of the first class are on much the same lines as safety hooks, and are not to be preferred to them. They do not safeguard the descending cage, and are of no use in cases of fast winding, but they prevent the engine from creeping or starting the wrong way. The second class do safeguard the descending cage;

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 85.

† *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 55-59, one plate.

they can be applied to shut off steam only, or to apply the brakes also when the cage passes a certain point independently of the speed, load, or steam pressure. If these vary, the apparatus still acts in the same manner, so that no discretion is allowed to the engineman, nor can allowance be made for varying requirements at different times. The author then proceeds to describe an apparatus named the "Visor," designed by himself, for overcoming some of these difficulties. Its mode of action is as follows:—When the engine attains or exceeds a certain speed, a governor rises and places a number of hooks in the path of beaked cams. If one of the cams is in a position corresponding with that of the cage, it will raise one of the hooks, and, by means of intermediate mechanism, will apply the brakes and shut off steam. If the governor drops before the positions correspond, the winding will proceed normally. Tappets are placed in the path of the cage, and are connected with the stop and brake gear, so as to apply them when the cage passes these tappets. Provision is also made for creep of the engines, and for preventing them starting the wrong way. The "Visor" prevents a fast overwind, but does not interfere with the engineman in any other way.

In some notes on Lancashire collieries, Mr. H. W. Hughes * also describes this device, and mentions other forms of indicators.

Mr. C. H. Corbold † also describes a patent apparatus, indicator, and valves for the automatic prevention of overwinding, devised by himself and Mr. W. Wood. A slide valve is controlled from a small steam-cylinder, so as to cover either the main supply to the engine or the steam-brake pipe. Steam is admitted to the small cylinder through a valve, which may be opened by a governor and a flanged disc connected with a pointer, so as to allow a system of levers to operate when the speed is excessive, or when the cage is too near the top of the shaft.

Wire Ropes.—Mr. T. H. Deakin ‡ gives a description of wire ropes and their use for winding purposes. The first wire ropes in England were made about 1840 by Mr. R. S. Newall, after he had received the suggestion from Germany. Steel wire was first used about 1860; and plough steel about five years later. The author gives tables showing

* *Journal of the British Society of Mining Students*, vol. xii. pp. 83-119, plates.

† *Proceedings of the Federated Institution of Mining Engineers*; vol. i. pp. 61-63, three plates.

‡ *Proceedings of the South Wales Institute of Engineers*, vol. xvi. pp. 305-334, seven plates.

the strength of various sizes and qualities of wire ropes by different makers. To make a good rope, the wire should be tough and strong, but much depends on the circumstances under which the rope works. As a rule, the lighter the rope the better it is, as long as ample strength is provided. The disadvantages of flat wire ropes are their shorter life, greater first cost, and liability to failure. If they have to be adopted, the drums should have solid cheeks, not arms, as the latter cut the stitches. Other varieties of rope are then described. In one form, around each strand is spun a wire covering, but the extra cost and weight would appear to counterbalance the diminution of wear. The advantages claimed for locked wire ropes are the evenness of wear and absence of tendency to twist. In some of these ropes the outer layer of locked wire may be stripped off when worn, and a smaller rope thus be obtained. The author questions whether these ropes are not liable to rust, and whether the outside wires will not have a tendency to elongate by wear, and so become loose and not take up their full strain. Difficulty of examination is also a decided objection. Westgarth's and Lang's patents are also mentioned. Ropes should be kept dry before they are oiled for use; when required, the rope should be uncoiled from a reel or turn-table, and thick oil should thoroughly be worked into the crevices; after this ordinary rope-oil may be used. The wear of wire ropes is then discussed. Broken ends should preferably be removed, and not tucked in, as they are then liable to cut. The pernicious effect of lifting the cage with a slack rope is pointed out, and the practice of loading cages without keeps or legs develops the same heavy strains and jerks. The use of hoops for securing caps is recommended in preference to ordinary rivets. The open cap allows inspection. The best way to prepare the rope for the cap is to wind fine wire round the rope about two feet from the end, which is then opened out, and the wires are bent back and tucked in, some being cut off to make a taper plug; the whole is then again wound with wire. Directions for splicing are given. The diameter of the drums depends on the size of the rope; an acknowledged rule for ropes of six strands of six wires is to allow one foot diameter drum for each lb. per fathom. For ropes made on Lang's principle, the diameter may be reduced one-seventh. Unless there is a very long distance between the drum and shaft-pulley, it is best to give the rope free play, as the whipping on a sheave does harm.

It is pointed out* that a wire rope should consist of wires of equal

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 47.

diameter and similar material; otherwise, the tension producing an unequal elongation, some of the wires are unduly strained. It is not possible to avoid this by variations in the method of laying the strands.

Colliery Winding-Ropes.—In the mining district of Dortmund, in 1887, at 91 collieries there were 201 winding-ropes, namely, 32 flat steel ropes, 4 flat aloë ropes, 156 round steel ropes, 9 round iron ropes.

Of the 3005 winding-ropes discarded during the sixteen years from 1872 to 1887, the following broke suddenly during working:—

Of 309 flat steel ropes, 21, or 6·80 per cent.

Of 147 flat iron ropes, 19, or 12·93 per cent.

Of 86 flat aloë ropes, 6, or 6·89 per cent.

Of 8 flat hemp ropes, none.

Of 1598 round steel ropes, 51, or 3·19 per cent.

Of 857 round iron ropes, 104, or 12·14 per cent.

Altogether, of 3005 winding-ropes, 201, or 6·69 per cent.

In 1872, out of 114 winding-ropes, 22 or 19·30 per cent. broke suddenly. This proportion gradually decreased, until, in 1887, out of 201 winding-ropes, 3 or 1·49 per cent. broke suddenly.*

Steam-Pipes for Collieries.—Mr. E. F. C. Davis† describes a combined screw and flange joint for colliery steam-pipes. The flanges are cast separately, and are screwed on to the ends of the pipes. The ends of the pipe and flange are then faced off flush with each other. The lugs are at the same time bored out, and the projections turned off concentric with the bore of the pipe, so as to ensure the continuity of the bore.

A New Mining Tool.—At the Friedrich Wilhelm I. and Hercules collieries at Habichtswalde, in the Cassel mining district, it has been found that the jumper employed was difficult to manipulate on account of its weight. To avoid this, the solid iron rod has been replaced by wrought iron gas-piping tipped with solid steel, and weighted at the other end by a heavy cast iron ball. The weight of the gas-tubing as compared with the solid rod is only as 5 to 12, and the new tool has proved most useful both in getting the coal and in drawing the props.‡

* *Berg- und Hüttenmännische Zeitung*, vol. xlvii. pp. 477-478.

† Paper read before the American Society of Mechanical Engineers. *Engineering and Mining Journal*, vol. xlviii. pp. 473-474.

‡ *Zeitschrift für das Berg-, Hütten und Salinenwesen im preussischen Staate*, vol. xxxvii. p. 127.

Friction of Colliery Waggon Wheels.—Mr. R. Van A. Norris * gives the results of experiments made during 1889 to determine the relative efficiency of the several styles of colliery tub wheels used by the Susquehanna Coal Company. Sections of the axles, bushings, and oiling devices are given. In the latest form the oil is carried to the bearing by spiral channels, and is thrown off centrifugally, so as to keep the oil circulating. All the wheels are of the loose outside type, 16 inches diameter on $2\frac{1}{2}$ -inch steel axles, with journals $5\frac{1}{4}$ inches long. Dynamometers of various sizes were used to measure the tractive force for starting and keeping up the speed, both slow and fast, with one and more waggons. Experiments were made on the level, on gradients, and also on curves, with empty and loaded trucks, and full tabulated results are given of the pull required. These show an economy in friction of nearly 40 per cent. in the use of tubs of the new type.

Carriage for Self-Acting Inclines.—Mr. J. Todd † describes a carriage designed for working large waggons on steep inclines. The large waggons could not easily be turned on plates, and it appeared dangerous to work them with cut chains, as used in East Scotland. The carriage is constructed with a sledge brake, which acts on the rails and is worked by a balance. It is constructed of angle iron, and is provided with a spring-controlled jock underneath, which is released if the rope breaks and runs into the ground to stop the carriage. The waggons are held on the rails on the carriage by a latch.

The Use of Electricity in Mining.—M. Przyborski ‡ draws attention to the rapid progress made of recent years by electricity as a source of power in mines. As a luminant and for shot-firing purposes its progress has been equally rapid. It frequently happens in mining regions that coal or other fuel is almost or quite prohibitive in price, and water-power not readily accessible. It is in cases such as these that electricity as a carrier of power from one spot to another plays perhaps its most important part.

The author discusses the subject under a series of headings, representing the more important of the applications of electricity in mines.

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† *Transactions of the Mining Institute of Scotland*, vol. xi. pp. 285-289, four illustrations.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 49-54, 68-71.

Under that of shot-firing he shows that not only is electricity safer and more certain in its action than ordinary methods of firing, but that its cost is less. Little need be said as to the value of electricity as a luminaut. Difficulties have, however, been experienced in its use owing to the necessities of mine-workings. The various hand-lamps are referred to, but not one is altogether satisfactory. Mine-signalling, hoisting and pumping, boring, ventilation, and other methods of utilizing electricity are also referred to, numerous instances being given of its application to such uses in practice.

Mr. T. V. Hughes* describes the application of electricity for mining purposes and for driving machinery generally. Explanations of the terms used and instances of plant to which it is applied are given. The author states that the problem of transmitting power by means of alternating currents has been solved during the last year.

The subject of electric transmission of power is also treated by Mr. A. T. Snell.†

The futility of makeshift arrangements in the electric installations of mines is pointed out by Mr. C. Hewitt.‡ The dynamos should be placed in a dry place, where moisture will not condense on them. The conductors should be properly insulated and supported, so as not to be affected by falls of the roof and other accidents. The author has devised a system in which the conductor that supplies the waggons is constructed in sections. Each section is separately connected to the main conductor, and is automatically thrown in and out of circuit by the passage of the locomotive. Cut-out boxes may be arranged to throw any section out of circuit in case it breaks down.

An electrical locomotive built by the Thomas-Houston Electric Company for the Hillside Coal Company, Pennsylvania, is illustrated in *Industries*. § The wheels are 3 feet gauge, the length 9 feet 7 inches, breadth 5 feet 3 inches, height 5 feet 6 inches; the weight is $4\frac{3}{4}$ tons, and the maximum speed is 6.2 miles per hour. The electro-motor is capable of supplying 40 horse-power. Suitable resistances are placed on the machine for purposes of regulation. The current is collected by a lazy-tongs arrangement from an overhead wire, and the return current is carried through the rails.

* Papers read before the *South Staffordshire Institute of Iron and Steel Works Managers*, October 2, 1889, and *Colliery Managers Association*, December 7, 1889; *Transactions of the National Association of Colliery Managers*, vol. ii. pp. 14-17.

† *Transactions of the National Association of Colliery Managers*, vol. i. pp. 196-218.

‡ *Engineering and Mining Journal*, vol. xlix. pp. 221-222.

§ Vol. viii. p. 209.

The electric haulage at this colliery is also fully described by Mr. F. A. Pocock.* A 60 horse-power engine at the top of the shaft drives a 50 horse-power generator. The conductors are carried down the shaft inside gas-piping to protect them from damage. Part of the current is utilised for lighting fifty incandescent lamps.

The locomotive is run by one man, who is assisted by a boy in making up the trains and turning the switches. It displaces seven mules and three drivers. During a period of $11\frac{1}{2}$ days the average number of waggons delivered at the shaft bottom by the locomotive was 559·5, against 526·95 per day delivered by mule haulage, much time being consumed by waiting at the bottom of the shaft for empty waggons. Up to the present the locomotive has shown that it will increase the daily output to 700 waggons per day. The operations are as follows :—

East or Slope Side.

Distance run per trip, including making up, &c.	2884 feet.
Time of trip	10½ min.
Waggons per trip	15
Trips per day	16
Miles run per day	8·73
Total time	2 h. 40 min.

Locomotive reversed 128 times per day.

West or Plane Side.

Distance run per trip, including making up, &c.	2546 feet.
Time of trip	6½ min.
Waggons per trip	25
Trips per day	26
Miles run per day	12·55
Total time	2 h. 50 min.

Locomotive reversed 104 times per day.

To deliver 700 waggons per day of 10 hours, the time of running the locomotive is 5 hours 30 minutes, leaving 4 hours 30 minutes for contingencies. The total distance run per day is 21·28 miles, and the locomotive is reversed 232 times.

Electrical Mine Haulage.—An electrical motor vehicle for haulage in mines is illustrated in the *Engineering and Mining Journal*.† The current is taken from a pair of overhead conductors by means of a trolley carrying four brushes, of which one pair takes the current when

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† Vol. xlix. p. 61.

the motor is going forward, and the other pair when reversed. The motor is mounted on a small truck with drawbars at each end, and is easily controlled by the operator. It is stated that speeds of $3\frac{1}{2}$ miles an hour are attained with loads up a grade of $4\frac{1}{2}$ per cent.

Another form of electrical locomotive is also shown * for use on an 18-inch gauge. The current may be conveyed in any suitable manner. Speed and direction are governed by the same switch.

Comparison of Electricity and Compressed Air.—Mr. H. W. Hughes † has collected details of cost and efficiency of electric transmission of power, and compares them with the cost of pneumatic transmission. At the Chapin mine in Michigan, air is compressed to 60 lbs. pressure at 60° F. by four turbines, and is conveyed through a 24-inch pipe for three miles. The pipe cost £12,000, and the total cost of the plant is estimated at £100,000. A test showed 1430 indicated horse-power at the compressors, and the sum of the indicated horse-power at the mines was only 390; the loss is therefore nearly 73 per cent., and this amount does not include friction of the compressors. The author gives a second case, in which a 500 horse-power turbine compressed air and delivered it three miles distant: The efficiency was 32 per cent. and the cost of the plant £84,000. An electrical company have agreed to give an efficiency of 60 per cent. from a similar turbine for a cost of £17,520, inclusive of the entire electrical equipment.

Pneumatic, Hydraulic, and Electric Mining Machines.—In a paper read before the Sheffield Society of Engineers, Mr. A. Lupton ‡ described the application of power for mining purposes. In most departments of industry the heaviest work is done by steam-power. In mines it is applied to the pump, the fan, and the winding-engine. Still, despite the amount of coal mining in Great Britain, it is probable that not 5 per cent. of the whole is got by the aid of steam-power. This seems unaccountable considering the cost of mechanical force as supplied by the steam-boiler and by human muscle. Steam, however, cannot be used in the confined working places of a mine without danger, and to transmit the power from the boiler on the surface

* *Engineering and Mining Journal*, vol. xlix. p. 111.

† *Transactions of the South Staffordshire Institute of Mining Engineers*, vol. xv. pp. 69-82.

‡ *Iron and Coal Trades Review*, vol. xl. p. 92.

to the workings, it must be converted into some other form. The four principal methods are the hydraulic, the pneumatic, the wire rope, and the electric. Hydraulic and pneumatic systems are well known to mining engineers, while electric transmission is comparatively new. Each system has its advocates, and each has its advantages and drawbacks. Electric transmission is used at several collieries near Leeds. Carrett & Marshall's hydraulic coal-cutter, brought out about twenty-four years ago, is described by the author, and also the hydraulic rock-drill used in some of the Cleveland iron-mines, where a small turbine mounted on a suitable standard rotates a twist drill at a high velocity, so that it bores into the stone at the rate of 3 feet per minute. Compressed air coal-cutters are next described. Firth's pick-machine, brought out twenty-five years ago, is still in successful use at mines near Leeds. Revolving wheel coal-cutters, driven by compressed air, are also successfully employed in some Yorkshire mines. Electric coal-cutters, patented by Messrs. Bower, Blackburn, & Mori, are now working at mines near Leeds. This machine does good work, and is very compact. Attention is next called to a new method of lighting miners' lamps. The lamp is lit by means of a platinum wire of peculiar construction, heated to incandescence by an electric current. The lamp may be trimmed and locked, and afterwards lighted when required without being opened. It can also be relighted in the mine without being opened and without danger.

Coal-Cutting Machines.—According to Mr. G. Blake Walker,* the revival in the coal trade, coupled with the fact that the thickest seams are rapidly becoming exhausted, has caused attention to be directed to thinner seams, that hitherto have not been considered worth working. Interest in coal-cutting machinery is consequently reviving. The jealousy as to machinery among the miners themselves has now completely disappeared, and they are distinctly favourable to its introduction, taking care, however, that the reduction in the severity of their labour shall not bring them any reduction in the actual money value of it. Coal-cutting machines have hitherto been used for three purposes—for heading, for holing, and for bringing down the coal. For heading, the Stanley machine is the only machine that has been made a practical success. It may be considered to have solved the problem of rapid progress, the progress made with this machine being

* *Transactions of the Federated Institution of Mining Engineers*, vol. i. pp. 123-139, with one plate.

a yard an hour. In a trial of twenty-four hours it cut 64 feet 6 inches. Machines for holing or undercutting the coal have to comply with a number of conditions. A machine for this purpose must be light, so as to be managed by two men working in a confined position, and strong, so as not to be injured by falls of the roof or by rough usage. It must be narrow and simple; it should clear its own cut, and be able to cut into the straight face at the start without having a hole made for it. There should be a reserve of power, so as to enable the machine to cut through nodules of pyrites or other exceptionally hard substances. Lastly, the cutting tools must be simple, and easily changed and sharpened. Amongst the most successful compressed-air machines may be mentioned Mr. W. Firth's pick, a machine introduced thirty years ago, and still at use at the West Ardsley Colliery; Baird's endless-chain machine, which has been largely used in Scotland; and the Rigg & Meiklejohn, Gillott & Copley, and the Winstanley rotary machines. The last is not at present in use, as it has not succeeded in cutting anything very hard. It has, however, many good points, especially that of being able to cut into the face. The Rigg & Meiklejohn machine cuts from front to back on the level of the foot of the seam, whilst the Gillott & Copley machine works in the opposite direction, and thus brings out its *débris* if the cut is above the floor. In Baird's machine the cutting is done by an endless chain with cutters attached, driven round an arm extending under the coal from 3 feet to 5 feet, as required. In eight to ten hours this machine will cut 2 feet 9 inches deep into 100 yards. Of American machines actuated by compressed air, the Legg coal-cutter appears to be the most successful. A number of electrical coal-cutters have been used in America, the Sperry, Bain, and Lechner machines appearing to have met with success. A new machine has been successfully tried at Messrs. T. R. & W. Bower's Allerton Main Colliery, and in ordinary working averages 150 yards per shift of eight hours. In comparing the actual cost of coal-cutting by hand and by machinery, experience shows that in a 3 feet seam the quantity of slack made when the holing was done by hand was 25 per cent., as compared with 15 per cent. when done by machine. In a seam 1 foot 6 inches thick the corresponding figures would be 45 per cent. and 30 per cent. respectively. A satisfactory performance in working a coal face by hand would be 100 yards per eight hours shift. The general result shows that, when machines are used, there is a saving of 8½d. to 1s. 6d. per ton, about two-thirds of which is due to the reduction in the quantity of small coal produced.

Machine Coal-Mining.—From the report on coal in Illinois in 1889, issued by the Bureau of Labour Statistics of that State, it appears that the number of machines used was thirty-seven less than in 1888, but the production was larger by 103,503 tons. The figures for the two years are as follows :—

Year.	Mines.	Machines. ‡	Tons.	Men Employed.
1888 ^d	39	272	2,213,210	3,088
1889	35	235	2,316,713	3,439

There is no material difference in the wages of the operatives. Most of the machines are used in bord-and-pillar workings in coal, ranging from 5 to 8 feet. The exceptions are at the mines at Spring Valley and Peru, where a 3½ feet seam is worked by the long-wall system.

The Michales mining-machine* is 9 feet long, 1½ foot broad, and 2½ feet high, and weighs 850 lbs. It is mounted with a two horse-power Tesla electric motor. In this motor there is no connection between the armature and the outside circuits, so that there is no sparking, and the armature can be well protected. The motor drives a screw-shaped cam, which surrounds the tool spindle and forces it back against the resistance of a spring. The tappet on the spindle carries an anti-friction bowl, and when this is released by the cam, the spring drives the tool forward and delivers the blow. A strong spring in the forward end of the spindle casing acts as a buffer if the tool does not strike the coal. The machine is supported on sliding axles, so that it can be properly balanced and directed by the operator. Results of tests in the hardest coal of Western Pennsylvania have proved satisfactory.

The Tesla motor has also been applied to the Hercules mining-machine† with success, after several trials with other motive powers. The machine measures 3 by 5 feet, and will undercut to a depth of 42 inches over an area of 600 square feet in ten hours.

Resistance to Air Currents in Mines.—Mr. T. L. Elwen ‡ has

* *The Electrician*, vol. xxiv. pp. 578-579, one illustration. *American Manufacturer*, vol. xlv. No. 13, four illustrations.

† *American Manufacturer*, vol. xlv. No. 5, one illustration.

‡ *Transactions of the North of England Institute of Mining and Mechanical Engineers*, vol. xxxviii. pp. 183-188, 13 plates.

made a large number of experiments to determine the resistance to air currents in mines. The instruments used were an aneroid barometer, reading to an altitude of one foot; a water-gauge, 4 inches square and 6 inches high, suitably protected from induction, and reading to $\frac{1}{100}$ of an inch; and a Casella's air-meter. Each airway was divided at several points, to avoid errors of leakage, into squares by strings, and the average velocity determined by readings of the anemometer in each square. In a straight airway it is found that the velocity near the sides is about 20 per cent. less than at the centre. Where the sides are rough or are timbered, the air is deflected towards the centre, and sets up eddies. Alternate contraction and expansion of the area has a most pernicious effect, as each contraction acts as a *vena contracta*. An enlargement of the area for a short distance does not always produce a good effect, as it may be more than compensated for by the additional head required to get up the velocity again. A change in the direction is effective in increasing the resistance. Details are given of experiments in various airways, and from them the author gives the following coefficients in lbs. per square foot of rubbing surface at a velocity of 1000 feet per minute:—

Shafts.	Intakes.	Workings.	Returns.
0·0037	0·0042	0·0137	0·0056

Greater accuracy will be obtained in calculation by treating the parts separately. Next to having the airways large, it is important to keep them as straight and regular as possible. Too little attention is generally given to the question of the junction of air currents. When they meet directly, the weaker current suffers; if they meet at right angles, the straight-on current has a most detrimental effect on the other. The amount of resistance may be reduced by erecting a brattice to bring the currents gradually together. The rule that the pressure required to overcome the resistance varies as the square, and the power as the cube, of the velocity, is practically confirmed by these experiments. It was noticed, however, that in very long airways the pressure does not always reach the point expected, owing to the momentum of the air, and, with increased velocities, this may become an important factor in the calculation.

Removal of Fire-Damp.—H. Brenner* gives an account of experiments carried on by D. Hilt at the König Colliery, Grevenberg,

* *Zeitschrift für das Berg-, Hütten und Salinenwesen im preussischen Staate*, vol. xxxvii. p. 70.

near Aachen, to determine the possibility of removing fire-damp by exhaustion. The seam varies from 6 to $6\frac{1}{2}$ feet in thickness, and from 20° to 50° in dip. A bord-and-pillar system of work is used and arranged so as to carry the air well up to the working face. A dis-used compressor was altered so as to exhaust at the rate of about 244,000 cubic feet per twenty-four hours. From the engine a pipe, $3\frac{1}{4}$ inches in diameter, was carried down the pit and for a distance of 1300 yards, when it branched off in 2-inch pipes for about 300 yards. Finally, pipes of 1-inch bore were led into the workings, and terminated in perforated rose-ends or boxes covered with wire gauze placed near the roof. Gauges showed a vacuum of $9\frac{1}{4}$ inches of water near the pit-bottom. This fell to 1.58 inch at the end of the main and down to 1.58 to 0.08 at the suction openings. A steam jet-exhauster was used, but with less success. The gases were exhausted alternately into one of two gas-holders at first, but afterwards they were sent directly to the delivery pipe. As a whole, the experiments were decidedly unsuccessful, as the gas varied so greatly, and so much attention was required to keep the pipes and roses in order. The gases were used under boilers, but without appreciable economy.

The Medium Fan. — According to Mr. A. Lupton,* the three conditions required of a fan are that it shall produce the required ventilation without breakdowns, with a maximum of economy and a minimum of outlay. In general a fan satisfies all requirements better than any other form of ventilator, but it is difficult to determine which is the best form of fan. The first cost depends on so many considerations quite apart from the principle of the fan; the liability to break down depends mostly on the workmanship; economy in working includes attendance, repairs, materials, and steam-power. It is difficult to determine the steam-power and the useful effect with absolute accuracy, in order to exactly compare fans working under ordinary conditions. The author has devised a fan called the "medium fan," which is a compound of the Waddell and the Guibal, with variations in detail. It is constructed to avoid extremes in design in accordance with the following statements. The weight of a fan varies as the cube of its diameter; the work done varies as the cube, and the water-gauge varies as the square of the velocity; the diameter of the fan-shaft is roughly proportional to the diameter of the fan, and journal friction is roughly proportional to weight multiplied by the velocity.

* *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 65-74.

When a large volume of air is dealt with, there is great friction and loss of power in a small fan; high-speed engines can be successfully employed. The fan is 15 to 25 feet in diameter, twelve vanes are carried by two steel discs $2\frac{1}{2}$ feet apart at the centre and 9 inches apart at the periphery. The air orifice is $7\frac{1}{2}$ feet in diameter. The fan is riveted to a cast-iron boss on a 7-inch shaft, with journals 5 inches in diameter, and is driven by a vertical engine with a $13\frac{1}{2}$ -inch cylinder and 2-foot stroke. The fan runs in a brick chamber, and discharges through a chimney. Particulars are given of a series of tests, which show an average useful effect of 73 per cent.; but some objection was taken in the discussion of the paper to the method of treating the friction.

Mechanical Ventilation of Collieries.—The arrangement and construction of the fans at several of the Lancashire collieries are described by Mr. H. W. Hughes.* Especial mention is made of the Guibal fan, with tapered blades, as designed by Mr. Cockson, and of Walker's V-shutter for reducing the jerk in the Guibal fan when the blades pass the outlet.

The subject of rotary ventilators (volumogens) is treated mathematically by J. Henrotte.† Formulæ are given for determining the volume exhausted, the efficiency of the blower and the motive power, the size of the blower, and the horse-power required. The means for finding the value of the various factors and constants are given, with curves showing the effect of resistance in the mine. These formulæ are worked out for the Fabry and Lemielle blowers. It is concluded that in a mine difficult to ventilate the blower may have a greater useful effect than the centrifugal fan, and the conditions for its efficient employment are not so varied as in the case of the latter. The volume exhausted is proportional to the number of revolutions, and the resistance of the mine and the depression of the water-gauge is proportional to the square of the revolutions.

A series of articles dealing fully with the subject of colliery ventilation is contributed by Mr. J. S. James.‡

Mr. M. Walton-Brown§ shows that the manometric efficiency alone does not determine the value of a fan. The theoretical efficiency is

* *The Journal of the British Society of Mining Students*, vol. xii. pp. 83-119, with illustrations.

† *Colliery Guardian*, vol. lviii. p. 737.

‡ *Ibid.*, vol. lviii.

§ *Engineering*, vol. xlix. p. 378.

never realised in practice, being influenced by imperfections in the fan and on the equivalent orifice of the mine. Formulæ are given for the determination of the effective manometric pressure and the volume of the air delivered by a fan. Some idea of the appropriate application of a fan is given by the ratio of the equivalent orifice of the mine to the orifice of discharge of the fan. When this is equal to or greater than unity, the fan is running under unfavourable conditions. A ratio of 0.50 may be taken as fair working practice, and if it falls below 0.30, the fan is most favourably proportioned to the mine.

The Microscopic Examination of Coal-Dust after Explosions.

—After every colliery explosion, as soon as the work of exploration commences, one of the chief problems which the manager usually tries to solve is, at what point did the explosion originate. It is doubtless very desirable to ascertain this correctly, but it is frequently extremely difficult to do so, owing to conflicting evidence, or perhaps the want of trustworthy evidence, and this being so, Mr. Palmer * thinks it may be useful to draw the attention of colliery managers to the assistance to be derived from the use of the microscope in the examination of coal-dust taken from underground roads over which fire is supposed to have passed. Of course, in places where definite evidence of burning is found, it is unnecessary to call in the aid of the microscope, but it frequently happens that strong conviction may be entertained that the blast has passed over a certain road, and yet dead bodies of men and animals, as well as shreds of hemp rope and other objects lying in that roadway, may show no apparent signs of having been burnt; in such cases as these, the microscope gives an immediate and unmistakable answer. The dust to be examined may be obtained from the under surfaces of balks, from the surfaces of props, or the wall-side; and it should always be as fine as possible, as the heat acts more strongly on the smaller particles, coking them into bright shining globules. No elaborate apparatus is needed to analyse a sample of dust: a student's microscope stand, with a 2-inch eye-piece and a 2-inch object-glass, which combined give an amplification of 25 diameters, being all that is required. At first some doubt was entertained as to getting constant results by this method, and, at the author's request, he was supplied with a quantity of samples of dust put up in packets, with nothing to indicate the locality from which they had been taken except a figure

* *The Colliery Manager*, vol. vi. p. 30; *Transactions of the National Association of Colliery Managers*, vol. ii. pp. 22-23.

on each packet—1, 2, 3, &c. These dusts were all taken from the St. Helen's Colliery, Workington, by Mr. J. B. Atkinson, H.M. Inspector of Mines, and after they had been examined under the microscope, a report was sent to him stating the results. He replied that from his personal examination down the pit, he considered that in five out of six cases the microscopical indication proved correct; and as regards the sixth, he could not say it was wrong. Dusts from Elemore Colliery, in Durham, and Mossfield Colliery, in North Staffordshire, have also been examined, and the author believes that in all cases where flame has passed along a roadway, its presence can be detected with certainty. Even in seams of non-coking coal, where the dust is not quite melted in bright globules, there will be fused and rounded edges, which when compared with dust from the same seam, form excellent signs on which to base a reliable opinion. In the case of Mossfield Colliery, the author found very evident signs of coking in a sample of dust taken from a balk-side, within a few feet of where two bodies were found, upon whom the doctor could discover no trace of fire. This was in a main return, and it was important to ascertain whether flame had passed along it.

Fire-Damp Explosions.—Mr. W. H. Mungall has calculated the pressure due to the explosion of fire-damp. From Dulong's experiments, 23,733 British thermal units are evolved by the combustion of one pound of fire-damp, and this heat tends to expand the gas or increase the pressure. When 9.09 per cent. of fire-damp is present in the air, there is just sufficient oxygen for its combustion. The reaction is $\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$. Accordingly 16 lbs. of fire-damp are burnt with evolution of 379,728 heat units and the production of 44 lbs. of carbonic anhydride, 36 lbs. of steam, and there are also 224 lbs. of nitrogen which accompany the 64 lbs. of oxygen. The specific heats of carbonic anhydride, steam, and nitrogen are 0.17112, 0.36400, and 0.17272 respectively. The total heat evolved is distributed among the products of combustion in proportion to their weights multiplied by their specific heats, so that the resultant temperature can be found by equating these quantities thus:—

$$x(44 \times 0.17112 + 36 \times 0.36400 + 224 \times 0.17272) = 379,728.$$

The temperature is thus found to be 6463° F. Assuming that no heat is lost, and the gas remains at a constant volume, the pressure will be in proportion to the absolute temperature before and after explosion,

and in this case, if the original temperature were 62° F., the pressure is 13·3 atmospheres. Similar calculations are made for other percentages.*

Electrical Safety Lamp.—A miner's electrical lamp, devised by Mr. L. Bristol,† has a four-cell accumulator enclosed in a box. The lid of the box covers one charging terminal to prevent short-circuiting, and it also secures the glass dome which covers the lamp. The active material of the plates is mixed with a fibrous substance to give strength. The following particulars of the lamps are given :—

Candle-Power.	Hours of Light.	Weight.		Height.
		Libs.	Oz.	Inches.
1½	10	3	6	5½
1½	15	5	4	6½
1	5	1	12	4

The Pieler Spirit-Lamp as a Fire-Damp Indicator.—Mr. M. W. Brown ‡ describes the Pieler spirit-lamp and its use as a fire-damp indicator. The lamp consists essentially of a large Davy lamp, constructed to burn alcohol, though methylated spirit may be used. A circular wick, preferably of silk, is passed over a round tube adjustable in height, and is surrounded by a short conical chimney. The flame should be adjusted in pure air, so as just to reach the top of this chimney. The lamp is protected by an iron shield with a graduated glass window. When placed in a mixture of fire-damp and air, the spirit flame shows a conspicuous cone of light, much larger than that in oil lamps; but when the percentage of gas exceeds 2 per cent., the lamp is liable to become heated and dangerous. Dr. K. Broockmann has made experiments on the indications with this lamp, and his results are fully given by the author, who also compares the records with those of other lamps. Indications can be obtained with this lamp from one quarter per cent., at which point a cone of dun-coloured light 1½ inch high is seen above the chimney. This cone increases in height to 5½ inches

* *The Colliery Guardian*, vol. lix. p. 441.

† *Engineering*, vol. xlix. p. 299; *The Electrician*, vol. xxiv. p. 581, one illustration.

‡ *Transactions of the North of England Institute of Mining and Mechanical Engineers*, vol. xxxviii. pp. 177-181, with three plates.

at 2 per cent., with an intense blue colour. Illustrations are given of the lamp and the appearance of the flame in various mixtures, both for this and for a Davy lamp.

The Langenbruch Safety-Lamp.—Experiments which have recently been made with this lamp at the Kaisergrube Colliery, Saxony, have not given the satisfactory results that were anticipated.*

The Wolf Safety-Lamp.—A description has appeared† of a modified arrangement for lighting this lamp. It consists mainly in a rearrangement of existing parts. The lighting is no longer effected by pulling down a knob, but by the twisting of a ring at the side of the lamp. Whether or not the new arrangement is of value appears to be doubtful.

Safety-Lamp Cleaning Machine.—A machine for cleaning the gauzes of safety-lamps is illustrated in the *Colliery Manager*.‡ A main driving shaft drives two reciprocating brushes by means of a connecting rod, and also operates revolving brushes. The gauze is placed on a post, and is arranged so that the movement of the reciprocating brushes partly revolves it, in order to prevent any part being acted on twice by the brushes. The revolving brushes are adapted for cleaning the ends. The reciprocating brushes clean the gauzes more thoroughly than revolving brushes, which have to work at high speeds to be effectual. The machine has few working parts, and is very simple in construction. It can be worked by a boy, and is capable of cleaning 1000 lamps per day.

The Use of Explosives in Mines.—The French Commission§ appointed to investigate the relative value of the more important explosives for use in collieries, have arrived at the conclusion that if such gas as may be present is not to be exploded on firing a shot, the temperature of explosion must not exceed 2200°. The lower it is, the less is the danger, and if the temperature does not exceed 1500° or

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1889, p. 113.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 73.

‡ Vol. v. p. 208, illustration; *Iron and Steel Trades Journal*, vol. xli. p. 96, illustration.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 54.

1600°, the danger of explosion is practically absent. The best explosives for colliery use are therefore those in which the temperature falls below this limit, and these are mainly mixtures of two compounds, the presence of one of which has for its object the reduction of the temperature of explosion. This substance is usually ammonium nitrate, the use of which is important in that it is of itself an explosive, and does not therefore diminish the force of the explosion, as an inert substance would. The temperature of combustion of the ammonium salt scarcely, if at all, exceeds 1000°. Experiments were made with a number of mixtures, and the value of ammonium nitrate for the purpose mentioned above was fully proved. It was much more efficacious than the other cooling substances experimented with.

The use of gelatine dynamite is rapidly spreading in Saxony. Comparative experiments made with gelatine dynamite and securite resulted in favour of the former, both as regards the quantity of explosive required to produce a definite result, and also as regards the resistance to the action of water.*

Numerous experiments with fire-damp dynamite (*Wetterdynamit*) explosives have been made in Saxony, but the results have not proved satisfactory, partly owing to its not being sufficiently powerful, and partly on account of the noxious character of the combustion products. Roburite, on the other hand, has given very satisfactory results both in rock and in coal, but this explosive has a tendency to absorb moisture, and so to become useless. Securite has also been experimented with, but the results are not conclusive. Carbonite appears to have given satisfaction. The use of the Paulus detonator has proved of great value.†

Blasting in Mines.—According to Mr. L. Gluck,‡ in Illinois and other central States two methods of blasting, known as the “needle” and the “barrel” methods, are employed. In the former method, the cartridge is inserted at the end of a copper needle, and the hole is tamped around the needle, which is then withdrawn to make way for the squib. In the latter method, the cartridge is inserted at the end of a copper tube, which remains and forms the passage for the squib. With the latter method coarser tamping can be used, and the operation takes much less time, while the safety is just as great as when a needle is used. The tubes are worn but slightly, and so there is considerable

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 131.

† *Ibid.*, p. 117.

‡ *The Engineering and Mining Journal*, vol. xlix. p. 223.

saving. At present only the needle method is legally recognised in these States.

Electric Mining Signals.—In some districts the clauses of the Mines Regulation Act relating to signalling are interpreted to mean that the signals should be such as to allow communication with the end stations to be made at any intermediate point on the line. When electric signals are adopted, this can only be done by using three wires instead of two. Mr. Rhodes* arranges the middle wire as a return wire for the other two, the top and centre wires as a communication to the engineman, and the bottom and centre wires to the far ends or shunts. This plan works very well, and affords communication with either end of the road. Some of the defects most likely to occur, with means of testing for and remedying them, are described. The signals should be tested every morning, and the batteries, bells, binding screws, and other parts overhauled, if the bell refuses to answer. All the connections should be tight, as total or intermittent stoppage is generally due to failure in this direction. Worn-out zincs or a diminution of liquid in the battery is a frequent cause of a breakdown. To preserve the batteries, they should be kept clean and dry. The existence of a current is easily tested by the taste. The adjustment of the bell and its connections requires periodical attention. Trembling bells appear to behave better than single-stroke bells. With the wires the most frequent cause of trouble is through their crossing, which short-circuits the current. This is due to falls of roof, breakage of insulators, &c. The joints in the wires also are troublesome, as they corrode, and, as a general rule, cannot be soldered *in situ* from fear of explosion. The best way is to scrape the ends, and bind them together with clean copper wire. The insulators should be kept in good condition. When fairly looked after, electric signalling gives very little trouble, and is a great advance on the old methods.

The subject of mine signals is also treated by Mr. J. Bloor,† who condemns the old bell-and-hammer method. Reference is also made to crossings, and the practice of men riding on the trams.

Mr. G. S. Corbett‡ describes a form of bell and generator for signalling in mines. The generator is a small magneto-electric machine, so arranged that, by pressing a button, the armature is brought near the

* *Transactions of the National Association of Colliery Managers*, vol. ii. pp. 14-17.

† *Ibid.*, vol. i. pp. 274-276.

‡ *Transactions of the Manchester Geological Society*, May 9, 1890.

fixed permanent magnets, so as to generate a momentary current. The device is contained in a water-tight case, through which the button spindle passes by means of a gland, so as to render it damp and dust proof. The desirability of combining a telephone system with the signalling device is also pointed out.

VIII.—*COAL-WASHING.*

The Sorting and Cleaning of Coal.—The Mining Institute of Scotland * has rendered valuable service to coal-mining by the appointment of a special committee of members who visited collieries in Great Britain for the purpose of examining and reporting upon the different machines and methods of cleaning, sorting, and preparing coal for the market. The report of the committee covers eighty-seven pages, and is accompanied by a volume of thirty-five plates.

The committee were afforded opportunities of inspecting various methods of coal-cleaning in operation, and in their report give ample descriptions, including details as to cost, &c. The following washing plants are reported upon :—The Bash washer, at the Cwm-Avon Works, South Wales, Glencleland Colliery, Wishaw, and Blairhall Colliery, Perthshire; the Bell and Ramsay washer, at Flimby Colliery, Maryport; the felspar (Coppée) washer, at the Cwm-Avon Works, Dowlais Works, and Celynien Colliery, in South Wales, Clifton Colliery, Manchester, Moresby Colliery and Whitehaven Colliery, Whitehaven; the Robinson washer, at Barrow Colliery, Barnsley, Clifton Colliery, Manchester, Earnock Colliery, Hamilton, Craighead Colliery, Blantyre; the Sheppard washer, at Llwynypia Colliery, South Wales, St. Helen's Colliery, Cumberland; and the trough-washer, at Llwynypia Colliery, South Wales, Aldwarke Main Colliery and Nunnery Colliery, Sheffield, Flimby Colliery, Maryport, Lodge Colliery and Longrigg Colliery, Slamanman.

In the Bash washer, the small coal from the screen is conveyed to the washing-tanks, where the water is agitated to separate the dirt, which falls to the bottom. The coal floats off at the top and is sized in a trommel. At the Glencleland Colliery, the two tanks are connected to a horizontal cylinder with a reciprocating piston for agitating the water. The dirt is removed from below the perforated screen by a

* *Transactions of the Mining Institute of Scotland*, vol. xi. pp. 145-231, and plates viii.-xlii.

valve. The chief defect is the rapid wear of the screen, which causes the loss of fine coal as the material is not sized.

Bell and Ramsay's washer is essentially a trough-washer with transversely oscillating stirrers. Movable stoppers are placed along the trough, which is lowered and the stoppers raised when the dirt is flushed out. Scum plates catch the floating material.

The felspar or Coppée washer separates the dirt, owing to its specific gravity being greater than that of felspar. Pulsation of water in the tanks allows the dirt to settle through the felspar and screens, while the washed coal is floated off above. For this process the coal is carefully sized by washing it through screens, or by other methods.

For the Robinson washer the coal has to be broken to a uniform size. The washer consists of an inverted conical tank with a vertical central shaft carrying stirrers. Water is supplied below, and the coal is fed in above. The upward current allows the dirt to sink, but carries the coal over screens placed around the tank to separate the water.

In the Sheppard washer a pulsating plunger causes the water to float off the coal, which is removed by a revolving brush, while the dirt settles and falls down an inclined screen into the main body of the tank. The coal passes over a screen through which the finer parts and the water fall. Screw conveyers remove the dirt and the fine coal from their respective compartments.

Trough-washers are simple open troughs with any required inclination. Stoppers or cross-bars are placed at the bottom, and the troughs may be double. The bottoms may be made of wood, glass, or iron. Self-cleaning troughs are at work at Longrigg Colliery. A set of travelling scrapers move along the bottom of the trough and carry the dirt with them, while the coal runs out at the lower end.

Besides the washers themselves, the report deals with hand-picking and dry cleaning, and the general arrangement of the pit-heads, with the transporting and tipping devices, are described and shown in the plates.

Subjoined are the general conclusions arrived at by the committee:—The methods and appliances in use in any one district can seldom be adopted as a whole in a similar form in another. This applies in many instances to collieries in the same district, and even to different seams worked by the same shaft. The nature of the coal, the associated and interbedded strata, the skill, customs, and prejudices of workmen, the markets to be supplied, the varying requirements of competition, and the caprice of the public, have all to be taken into

account when designing plant for classifying and cleaning coal. While coal with marked characteristics can with care be selected underground so as to be filled separately, no process can be profitably applied underground for effectually removing refuse, especially the smaller particles. To clean coal properly, it must be treated on the surface. As a considerable percentage of smalls are obtained in transit from the cage to the railway waggon, it is evident that the best results are got where attention is paid to the form of waggon and tumbler, the inclination of screens, and the drop into waggons; and this is specially important in the case of soft coals. A number of contrivances to lessen breakage are mentioned in the report. The careful hand-packing of large coal into the waggons, as practised in the Nottingham district, has advantages. For effective screening, especially when a large output has to be dealt with, there appears to be no better contrivance than the single or double jigger, or shaking screen, going at from 90 to 100 strokes per minute, and having an inclination suited to the class of coal to be treated. There is a preference for wire-meshing for such screens at some collieries, and at others bars or perforated plates are preferred. For picking, the shaking screen just referred to, or the travelling band, or both combined, is the most effective and economical—the band being about 4 feet wide, 40 to 60 feet long, and moving at a speed of from 30 to 60 feet per minute, according to the quantity of coal to be passed. Ample length of band allows large coal to be sized and loaded into separate waggons by hand with despatch and economy. In every case it is necessary that the coal be delivered regularly from the tip-hopper to the jigger or travelling band. This can be accomplished by regulating sluices worked by an attendant, or automatically by the intervention of a slow-motion band. Good light is essential to efficient picking. A rough rule for deciding the number and length of picking tables may be stated as follows:—One picking table for every 30 tons per hour of coal output, travelling at the rate of 40 feet per minute, and having an effective length of 10 feet for every 3 per cent. of material to be picked off, *plus* 15 feet. The cost for labour of this system may be taken at about $1\frac{1}{2}$ d. to 2d. per ton of round coal for every 5 per cent. of material picked out of that coal. For round coal, say above $1\frac{1}{2}$ -inch cube, the dry process is universally employed, and this process can be successfully applied to nuts from say $\frac{3}{4}$ inch upwards, where the refuse does not exceed 2 to 3, or even 4 per cent.; and the table capacity required, judging from the examples in the report, is about one table for every 20 tons per hour, travelling at the rate of 30

feet per minute, and having an effective length of 15 feet for every $1\frac{1}{2}$ per cent. of material picked off. The cost for labour will probably be from $\frac{3}{4}$ d. to $1\frac{1}{4}$ d. for every one per cent. picked off. Balanced screens, on which the coal is picked, are available only when the amount of material to be picked off is very small, say 1 to $1\frac{1}{2}$ per cent. For all small under $\frac{3}{4}$ inch, and for material from $1\frac{1}{2}$ inch downwards, with more refuse than from 2 to 4 per cent., the wet process is most applicable. In the wet process it is desirable to have the arrangement so that the small coal can be delivered direct from the screens into the washing-tanks without the intervention of waggons. In all the systems of washing, the best results are obtained by sizing the small coal before it reaches the machine. This can most conveniently be done by passing it through revolving screens with meshes of varying size. The supply and degree of pulsation or agitation of the water require careful adjustment to suit the various sizes of coal to be treated, and the relative specific gravity of the coal and impurities. To remove the refuse from the smaller sizes, say under $\frac{3}{8}$ inch, the felspar washer is the most effective. The felspar system is the most valuable where the coal is crushed before washing and is to be used for coke-making. Where the coal and the refuse approach one another in specific gravity, it appears that in some cases the trough-washer gives the best results. It is applicable for small quantities only, and requires a large flow of water and extra labour, but it has the recommendations of simplicity and small capital cost. It may also be sometimes utilised as a means of transport where the distance from the pit to the waggons or coke-ovens is considerable. The Robinson washer is cheap as regards first cost and upkeep, and requires little water. It largely depends for its efficiency on the attention and skill of the man in charge, who may often be tempted to 'pass more through it than it can effectually clean. As a rule, more elaborate machinery is effective in avoiding waste in proportion to its cost, but the capital charges and upkeep are also high in proportion. Other things being equal, coal will be washed best with an abundant supply of clean water; but the more water used, the greater the risk of fine coal being lost, and the greater the difficulty of filtration. Water to wash coal for coking should not be used over again often, as dirty water dulls the coke. The particulars furnished as to settling ponds do not give sufficient data to justify any definite conclusion as to their capacity in relation to the quantity of coal washed. In most cases no record was kept of the quantity of water used; but settling ponds are a necessity, and their capacity will depend on the special circum-

stances of each case. There seems no better way of filtering the foul water, after it has passed through the settling ponds, than pumping it on to the rubbish heap, and allowing it to percolate through, as at Earnock. The washed very small coal not suited for coking is meanwhile used almost entirely for firing colliery boilers. Briquettes are made of it to a small extent, but new outlets are required for this product. The large quantity to be treated daily, and the varying nature and proportions of the coal and dirt to be separated, render washing, at most collieries, a troublesome process; and unqualified satisfaction is seldom expressed as regards any machine in use. In some cases the machine may not be quite adapted to the peculiarities of the coal treated, or it may be overdriven, or not have a sufficiency of water, or be allowed to get out of repair, all or any of these causes leading to disappointment as to results. A separate siding for each class of coal is a desirable arrangement. While the investigations of the committee have not led them to prefer and recommend any particular system as the best in all circumstances, the examples given will, it is hoped, be valuable in directing attention to the conditions in which each system reported on is likely to be most successful and profitable, leaving it to individual skill and judgment to adapt and modify as special circumstances may require.

Screening and Cleaning Coal.—Messrs. T. E. Forster and H. Ayton * describe certain details of plant used for screening and cleaning coal, and then proceed to discuss the main principles and points that have to be considered in laying out a plant for any definite purpose. As regards the motive power, the engines should be as near the work as possible, so as not to complicate the gearing. Belts are now usually driven from the back end, except they are long and heavily loaded. Belts and screens may usually be driven from the same engine. Screens are divided into two classes—main and secondary. The main screens take the whole produce of the colliery, while the secondary screens separate the smaller sizes of coal. The size and arrangement of the screens are then considered, and also the material for the screening surface, which may consist of steel bars, square wire gauze, locket-work, or sectional locket-work. The secondary screens are in general a reproduction of the main screens, and are fitted as a rule with square wire gauze. Various forms of belts are next de-

* *Proceedings of the Federated Institution of Mining Engineers*, vol. i. pp. 83-98, ten plates.

scribed; the question of their speed is considered, and the necessity of duplicating the belts is pointed out, so as to make provision for break-downs. For loading shoots, a telescopic plate is recommended, but none of the devices for minimising the fall from the belt appear to be particularly successful in practice.

The subject of the arrangement of the plant is considered under two heads. First, where the screening precedes the cleaning; second, where the coal is cleaned with or without subsequent screening. The first is the most usual system, and is best when the output is classified and no large proportion of unscreened coal is made. When small coal has to be picked, it is most easily and economically performed on a separate belt. Where the proportion of unscreened to be made is large, it is better to tip the coal directly on to the belt, and to place the screen at the leading end, so that the unscreened coal may be loaded direct. In any case a large area of belt space is required, and the best results are obtained with a series of short belts, any one of which can be stopped if the coal on it is particularly dirty. When small quantities of unscreened coal are required at irregular intervals, a dumb spout feeding directly on to the belt may be employed, or a plate may be fixed over the gauze when the screens and belts are in line. At Cowpen Mill pit, the best and small are remixed by a trap at the screen-foot. For the disposal of the pickings a stone partition in the middle of the belt has been largely adopted with considerable advantage in some cases. Separate collecting belts have been proposed. The difficulties anticipated with regard to laid-out tubs have been found to be very slight, as a man is stationed at the foot or side of the screen to mark the belt where an undue amount of refuse is left.

The particular design of a plant is dependent on the local conditions, and may be governed by the already existing buildings. It is perhaps preferable to arrange screens and main belts in one line if practicable where double screening is used without re-elevation, as this allows the different classes of small to be more easily loaded on to separate roads by means of cross-belts of different lengths. For single screening it is most suitable to arrange the belts at right angles to the screens, and so utilise already existing buildings. Duplicate belts should run in different directions in line with each other, and load from their respective ends by curved shoots, so as to prevent a difference in the length of the screens. The authors then proceed to give a description of the plant at Mill Pit, Blyth, St. Hilda Colliery, and Beamish Colliery, and then give full tabulated details of the plant at eleven

collieries. These details show the time, quantity treated, amount of coal of various descriptions, and the dirt produced, dimensions and speed of belts and screens, labour, wages, and cost. Among other advantages of mechanical screening there is considerable economy in concentration of labour for banking out. When possible, a system of banking by gravitation should be employed, and the tubs should preferably be of a side-teeming type. A sliding cover is illustrated for end-teeming waggons when they have to be employed. The empty tubs, after leaving the kick-up, should be raised so as to gravitate into the cages by means of a creeper or chain with projecting arms which engage the tubs. Full illustrations are given of the various devices referred to in this paper.

In a lengthy report on some Lancashire collieries, Mr. H. W. Hughes* describes the screening and washing arrangements at Pemberton and Brinsop Hall collieries. At the latter colliery the screen which delivers the coal on to the picking belt is divided into two parts, of which the upper has an inclination of $14\frac{1}{2}$ inches per yard, and the lower of $19\frac{1}{2}$, and the upper bars have an oscillating motion given to them by an eccentric. A subsidiary belt is used to remove the dirt, and is made of old flat steel ropes. The plant at the Hewlett pit of the Wigan Coal and Iron Company is also described.

A New Coal-Screen.—Mr. G. C. Greenwell† describes a new form of screen for picking and screening coal, which has been in use for the past two years at the Poynton Collieries. It consists of a series of parallel, short-linked, endless chains, driven by engine-power, and working between fixed bars of a particular section and of various widths. The coal is tipped on the screen and carried forward by the chains, which travel at a slow speed. The various sizes drop between the bars into waggons placed below, and the dirt is picked out by the pickers who are stationed on either side. The screen may be of any length, and, by using a sufficient number of guiding pulleys, the coal can be accurately sized. In the two screens now at work, the speed of the chains is 73 feet per minute, 100 tons are dealt with hourly at a cost of one farthing per ton, and the first cost of each screen is under £100. In the discussion it was stated that the fixed bars are horizontal, and that the shaking of the chains as they pass over the pulleys prevents clogging and efficiently screens the coal.

* *The Journal of the British Society of Mining Students*, vol. xii. pp. 83-119, illustrations.

† *Transactions of the Manchester Geological Society*, vol. xx. pp. 440-444, one plate.

Coal - Washer.—A coal-washer designed by Mr. G. Lauder is illustrated in the *American Manufacturer*.* Three four-compartment washers of this design, with a capacity of 1800 tons per day, are being erected at Bellefonte, Pennsylvania. The coal is crushed to a uniform size and is not classified. It is distributed from a trough behind a baffle-plate in the washing-tank to ensure its even distribution over the perforated screen, which is made of copper. The plungers are driven by eccentrics. A movable dam is placed in the centre of the tank, and the washed coal is forced over it, and is removed by paddles on a rotating shaft, which force it over into a draining-tank. The shale is removed intermittently by raising the central dam and raking it out, and a gate is provided at the bottom of each tank for sluicing out the fine dirt.

* Vol. xlv. No. 5, one illustration.

PRODUCTION OF PIG IRON.

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I.—BLAST FURNACE PRACTICE.

The Effect of Velocity and Tension of Gases on the Blast Furnace Process.—Mr. T. W. Robinson * examines the views held by Mr. E. Walsh † that a furnace of contracted stack and throat, on his lines, may equal in output, per unit of air blown in, one of considerably greater cubic capacity. The suggested explanation of the theoretically greater capacity per cubic foot of his furnace is that the increased tension of the gases, caused by passing them through the smaller area, will promote transpiration, thus facilitating reduction and permitting more rapid driving. For the successful achievement of what would be unusually rapid reduction, Mr. Walsh relies upon the results of Sir Lowthian Bell's experiments on the relative reducing effects on ores of gases flowing with different velocities, which showed that the greater the velocity of the gases the greater the reduction. The author conducted some experiments to test Mr. Walsh's views, with the result that, under equal conditions of ore, gas, tension, temperature, and quantity of gas, but with a velocity in one case twice as great as in the second, the reduction was nearly 2 per cent. greater with the slow than with the rapid current. He considered that the difference was due to slight variations in manipulation, and that under the conditions employed increased velocity of flow of the reducing gases does not produce sufficient increase of reduction to prevent its

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† *Journal of the Iron and Steel Institute*, 1887, No. I., p. 392.

being marked by slight and unavoidable discrepancies in experimenting. A second series of experiments, undertaken to ascertain the effect of the pressure of the gases in their action on the ore, shows that pressure alone, other things being equal, has the effect of increasing the reducing power of the gases. The methods of experimenting and the apparatus used are fully described.

Peculiar Working of a Blast Furnace.—Mr. N. B. Wittmann* describes the behaviour of two blast furnaces of the E. and G. Brooke Ironworks. They have the following dimensions :—

	No. 2.	No. 3.
	Feet.	Feet.
Height	55	60
Diameter at bosh	15	16
„ hearth	8	7½
„ stock-line	10	9½
Height of bosh	23	23
„ tuyeres	5½	5
Diameter of bell	7	6
Front	closed	open

The ore mixture is practically the same for both furnaces, and consists of 75 per cent. of magnetites and 25 per cent. of hæmatites. About 40 per cent. of the magnetic ore contained a variable amount of calcite, ranging up to 8 per cent. The sulphur is also variable, and has a general average of 2½ per cent. Only about half the sulphur can be removed by roasting, as the remainder combines with the lime. The free calcite causes considerable difficulty, as it is almost impossible to apportion the flux properly. Some of the ore, too, disintegrates readily. The fuel used is anthracite, with 20 to 30 per cent. of coke, and dolomite is used as flux. About 1·8 ton of ore and 0·8 ton of flux produce a ton of iron, and the slag has approximately the following composition :—

SiO ₂ .	Al ₂ O ₃ .	CaO and CaS.	MgO.
35·0	12·0	33·0	20·0

As an instance of satisfactory work, No. 3 furnace produced 18,422 tons in nine months, with a fuel consumption of 1·19 ton per ton of iron; the best week's out-turn was 531 tons, made with 1·05 ton of fuel per ton. This furnace was filled and blown in with a hearth full of

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

wood saturated with oil, on the top of which were 26 tons of coke and 2 tons of grey furnace slag as flux. Ore charges were commenced with 1000 lbs. each of anthracite and charcoal, 1300 lbs. ore, and flux to form a slag with 39 per cent. silica. The burden was increased 200 lbs. every six charges until the stack was full, after which the fuel charge was two parts anthracite to one of coke. The maximum blast was attained in ten days, and the furnace worked satisfactorily for three years.

Furnace No. 2 was blown in during November 1888, as nearly as possible in the same way, but the work for the first nine months was vastly different. The iron was an ordinary grey forge pig iron; but when more burden was added, the iron became closer in grain, and evidence was soon given that the furnace was overburdened. The only abnormal feature was the low pressure of blast, which remained at about $5\frac{1}{2}$ lbs. per square inch for three months, instead of rising to 7 or 8 lbs. as usual with a fuel mixture of three-quarters anthracite and one quarter coke. Ring-scaffolding seemed to be indicated; so a fuel blank of 20 tons with scrap was charged, and the speed of the engine was reduced after ten hours, in order to enable the blast to work up the walls. It appeared, however, that the melting zone was in the region of the boshes, and that there was no considerable accumulation on the walls. The working was not improved by this treatment. The best week's work during July and August was 445 tons of pig iron, with a fuel consumption of 1.3 ton per ton of iron. It was then discovered that the hot blast stoves were out of order, and for some time, owing to an accident, the furnace had to be run with one stove of twenty-eight pipes and a blast temperature of 600°. When the furnace had started again, the pressure of the blast gradually rose to 7 lbs., but the fuel consumption rose and the output fell off. For five weeks the average consumption was 1.508 ton of fuel, and weekly production 361.8 tons. During casting, about one-third of the slag ran very hot and fluid, then a mass of buckshot, followed in turn by hot fluid slag free from buckshot. In the author's previous experience buckshot only appeared when the slag was cold. The appearance of the slag was unusually good, and, moreover, it was uniform, whether buckshot appeared or not. The top of the furnace was as cool as could be expected with such a light burden, and the gas was clean and good.

For several days, owing to a coke strike, it was necessary to increase the anthracite to $87\frac{1}{2}$ per cent., and this resulted in less iron and more buckshot. In the first week of September a slight improvement was noticed, although no change had been made in any particular. The

iron was a good grey forge pig iron, with an appearance which seemed to show that it was greyer than the grain indicated. The burden was increased till 800 lbs. more ore were carried by 2000 lbs. fuel, and the make, for the five weeks, ending in October, averaged 464·6 tons, with 1·206 ton of fuel. The percentage of coke was again temporarily reduced without producing such serious effects as had been experienced before. At the present time, the average production is 69 tons daily, with a fuel consumption of 1·2 ton, containing 20 per cent. of coke. At the same time the slag is most irregular, varying from bluish-white with stony fracture to black with vitreous fracture. The stock slips 4 to 6 feet at flushing, whereas formerly it settled regularly.

Scaffolding in any form could not be detected. The proportion of fine ore was not changed, and so could not have affected the working. In conclusion, the author confesses his inability to account for the irregularity in the working of this furnace.

Mr. H. S. Fleming had a similar experience with a furnace, the dimensions of which are as follows :—

	Feet.
Height	75
Diameter at bosh	16
„ „ hearth	10
„ „ stock-line	13
Height of bosh	27
„ „ tuyeres	6½
Diameter of bell	9

At first a mixture of Centre County, Lake Superior, and Clinton ores was used. Shortly after blowing in, buckshot was produced, but this was remedied by doubling the fuel charge. After this the burden was increased, and since then the furnace worked well with one exception. This was when working with a slag containing 39 per cent. silica, with dirty coke, and with a very irregular mixture. This was remedied by increasing the limestone and fuel. In replying to the discussion on his paper, Mr. Wittmann stated that the fuel in his case had been increased, but had not produced the required effect in No. 2 furnace. He could not increase the basicity of the slag without danger of cooling the hearth and loosing the iron notch. Of all the suggestions offered, the author was most inclined to the theory of dirty walls.

Unreduced Ore Passing Through a Blast Furnace.—Mr. E. S. Cook * describes some specimens of ore which have passed through the

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 303-305.

blast furnace. The ore was from the Republic mine in the Lake Superior district. Some of the pieces were only partially deoxidised on the surface, and some were encased in a covering of what appeared to be wrought iron. The furnace had been running on one lining, and had produced 108,000 tons in three and a half years, at the rate of 650 to 710 tons per week, although it is only $55\frac{1}{2}$ by $15\frac{1}{2}$ feet. During February 1889 the yield fell below 600 tons, and by March, part of the brickwork in the boshes had melted away, and had been replaced by a mixture of carbonaceous material, lime, and finely divided ore. This filling slipped down *en masse* into the crucible, and so reduced the temperature, that the iron and slag notches were closed and the tuyeres were kept open with difficulty. The slag in the tuyeres was discharged by slagging-valves in the belly-pipes, and the furnace was run on silver-grey iron with the hope of re-forming a graphitic bosh, which was only 2 to 3 inches thick, on the west side. The furnace on this side was much hotter and worked better than on the other side, where the tuyeres were rapidly cut by iron accumulating in pockets round them. It was from this side that the specimens of reduced ore were collected. It was supposed that the blast did not act much on the east side, so that the ore was not reduced, and this tended to further chill the hearth. To remedy this condition of affairs, a long tuyere, projecting 20 inches beyond the breast, was placed on this side, and the nozzles on the other side were contracted from 5 to 3 inches in diameter. This soon remedied the defects, and no more unreduced ore came down to the tuyeres, even when the stock was only twelve hours in the furnace. The presence of the unreduced ore therefore seemed to be due to the imperfect distribution of blast caused by the shape of the furnace, and not to rapid driving.

Manufacture of Basic Pig Iron.—According to Mr. H. Pilkington,* basic pig iron to suit the requirements of the South Staffordshire district should not contain more than 1 per cent. of silicon, or 0·10 per cent of sulphur. Half these quantities constitute a good pig iron, which should also contain 1·5 to 2 per cent. of manganese and 2·5 to 3 per cent. of phosphorus. In order to produce pig iron of this character, it is necessary to work the furnace with a very basic slag, and at such a temperature that the iron shall be white in order to keep the silicon low. On the other hand, the furnace must be sufficiently

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, March 15, 1890.

hot to keep it in working order, and also to allow the sulphur to escape in the slag. Tap cinder and Northampton ore are used to regulate the phosphorus. Lincolnshire or Oxfordshire ores may be used to give basic material instead of adding lime. Suitable manganese ores must be chosen to supply manganese to the metal and to keep the slag liquid. Slag from the manufacture of spiegeleisen is often a cheap source of manganese, but it is present as silicate, and so tends to remain in the slag, or else the silicon is likely to be liberated simultaneously with the manganese. Rich manganese ores have similar defects, so that the best ore to use is calcined spathic ore. The presence of manganese in the charge enables the required conditions of work in the furnace to be complied with by reason of its fluxing power, and also because it liberates lime to combine with the sulphur. The following is a typical analysis of the slag :—

FeO.	Al ₂ O ₃ .	MnO.	CaO.	MgO.	Alkalies.	S.	SiO ₂ .	Total.
1·52	12·12	2·10	51·13	0·22	0·50	0·89	31·21	99·69

The iron contains on an average—

P.	S.	Si.	Mn.
2·79	0·04	0·36	1·90

Hard coke must be used when so much lime is employed, or else the furnace has a great tendency to gob up and chill. With furnaces 56 to 60 feet high, producing 280 to 350 tons weekly, the coke consumption should not exceed 21 to 22 cwts. of coke, with a blast at 950° F.

Charcoal Blast Furnace Records.—According to Mr. J. C. Ford,* the Spring Lake Iron Company's furnace at Fruitport, Michigan, was blown in during March 1880, and has given the following record :—

	Total Days.	Stops.	Net Days.	Tons of Pig Iron Made.	Tons of Pig Iron per Day.	Bushels of Charcoal per Ton of Iron.
1st blast . .	677	7	670	29,040	43	94
2nd blast . .	799	7	792	33,124	42	95
3rd blast . .	331	11	320	15,279	48	89
4th blast . .	510	14	496	26,868	54	88
5th blast . .	586	10	576	29,237	51	92
6th blast . .	361	10	351	20,451	58	95
Totals and averages }	3264	59	3205	153,999	48	92

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 272-274.

The ton of iron is weighed out at 2260 lbs., and the bushel of charcoal averages 20 lbs., and is made in brick kilns. The furnace is 45 feet high, 10½ feet in diameter at the boshes, and the crucible and bell are both 5 feet in diameter. The ore mixture averages 58 to 61 per cent. of iron, and comes from the Lake Superior mines. The blast averages 850°, and is supplied through four 3½-inch tuyeres.

The Hinkle furnace of the Ashland Iron and Steel Company is 60 feet high and 12 feet in diameter at the bosh. The blast is heated to 900°. It was blown in during April 1888. The record is as follows :—

Working Days.	Total Out-turn. Tons.	Average Out-turn. Tons.
73	3,261	44·67
316	26,137	82·71

Since September 1889 the daily out-turn has, according to Mr. M. R. Hunt, averaged 90 tons.

Blast Furnace Record.—Mr. J. Gayley * publishes what is described as the best blast furnace record ever made. It relates to F. blast furnace of the Edgar-Thomson Steelworks, Pennsylvania. This furnace was blown in after re-lining on September 25, 1889. The record for the next three months was as follows :—

	Bessemer Iron Produced.	Pounds of Coke Used per Ton of Iron Made.
	Tons, gross.	
November	9,097	1897
December	10,603	1756
January	10,536	1737
Best week's out-turn . .	2,462	1702
Best day's out-turn . .	457	...

The Durham Blast Furnace.—The filling and blowing in at the Durham blast furnace is described by Mr. B. F. Fackenthal † with the view of showing that it is not necessary to make a quantity of white or silver-grey iron at the start, or to spend weeks in bringing the furnace to its proper burden. A description of the furnace plant has previously been given by the author.‡ A summary of the first seven blasts is now given, and details of the filling and blowing in for the

* *Iron Age*, vol. xlv. p. 253.

† *Transactions of the American Institute of Mining Engineers*, vol. xviii., two plates (advance proof).

‡ *Journal of the Iron and Steel Institute*, 1885, No. II., pp. 714-715.

blasts Nos. 3 to 8. During the first and second blasts no coke was used, and the furnace ran irregularly. For the third and fourth blasts, after putting in the bed, a burden of 50 cwt. of ore was used, and increased every fourth charge by 5 cwt. till the furnace was full, with a burden of 80 cwt. of fuel to 100 cwt. of ore. The first and second casts were mottled and white pig iron, the third and fourth were silver-grey, after which No. 2 and grey forge pig iron was produced. For the next two blasts the burden was decreased at first, but increased more rapidly than above, with satisfactory results, as the iron at the first cast was a good, strong grey forge in the last of these two blasts. The same practice was carried out for the seventh and eighth blasts, similar good results from a final burden of 80 cwt. of fuel to 108 cwt. of ore and 60 cwt. of limestone. In filling a furnace, the author puts a scaffold of wood up to the level of the tuyeres, leaving an open space underneath, instead of placing the wood directly on the hearth, where the air cannot get at it. Kindling wood is placed at the tuyeres and lighted all round. If the scaffold is put in with care, there is no special danger of irregular settling of the stock. On the scaffold wood is placed horizontally, and above that three tiers of wood placed on end, and on top of this the fuel. Sketches of the furnace at each blast are given, and also a diary of the behaviour of the furnace during the first week of the eighth blowing in.

An Old Blast Furnace.—An old-fashioned blast furnace is illustrated in the *Journal of the United States Association of Charcoal Iron Workers*.* It was built in 1844 in Carter County, Tennessee, and was run for forty years as a cold-blast furnace with charcoal as fuel. The out-turn never exceeded six tons per day, but the iron was very good, and wheels made from it have endured sixteen years mileage.

The Bethlehem Ironworks.—Mr. W. H. Jaques † has published a description of the Bethlehem Ironworks, Pennsylvania. The works include blast furnaces, puddle mill, merchant steel mill, Bessemer department, department of construction and repairs, ordnance and armour-plate department, the whole covering about 18 acres. There are mines and quarries in connection with the works.

The blast furnaces are seven in number, and were constructed

* Vol. viii. pp. 301, 302.

† *Proceedings of the United States Naval Institute*, vol. xv, No. 4.

between the years 1860 and 1883. The dimensions of the more recent ones, built since 1875, are as follows:—

Furnace.	Height.	Diameter at Boshes.	Diameter at Hearth.
No.	Feet.	Feet.	Feet.
4	70	16	10
5	70	16	10
6	70	19	10
7	65	16	10

These furnaces make excellent Bessemer pig iron from a mixture of hæmatite and magnetite ores. The fuel is a mixture of anthracite coal from the Upper Lehigh Valley and Connellsville coke.

The blowing engines, which are of the horizontal compound type, work at a high speed, and are capable of delivering the blast at a pressure of 20 lbs.

Blast Furnace Lining.—An attempt has recently been made by the Crown Point Iron Company,* Lake Champlain, New York, to glaze the interior of the lining of a blast furnace. The lining was coated with a paste of cheap graphite and water. It is stated that the experiment has been a success, and that the lining is kept free and clear.

Coke Bricks in Blast Furnaces.—F. Burgers† points out how great is the corroding action of the slag in a blast furnace on the bricks forming the furnace walls. To avoid this, in the works under his direction experiments were made with a view to testing the efficiency of bricks of ground coke, poor in ash, with tar as a binding material, a mixture similar in character to the retort carbon and tar used in France. These coke bricks have given excellent results.

New American Blast Furnaces.—The Illinois Steel Company is erecting four new blast furnaces, each 85 by 21 feet, at the South Chicago Works of the company. Each blast furnace will be supplied with four Massick and Crooke hot-blast stoves, having the dimensions of 22 by 70 feet, with 30,000 square feet of heating surface per stove.‡

* *The Engineering and Mining Journal*, vol. xlix. p. 388.

† *Stahl und Eisen*, vol. x. p. 112.

‡ *Iron Age*, vol. xlv. p. 95.

They will be equipped with ten vertical engines, having blowing cylinders 84 inches in diameter, and steam cylinders 42 inches in diameter, the stroke being 5 feet. The boilers will be 40 in number, tubular, 20 feet in length and 5 feet in diameter.*

A new blast furnace is to be erected at Etna, Pennsylvania, by the Isabella Furnace Company. The furnace will be 75 feet in height, with a diameter of 17 feet at the boshes. Another furnace, to be erected at Roanoke, Virginia, will have the same diameter as the one just mentioned, but will be 82 feet high.† Another new furnace, of the same diameter and a height of 75 feet, is to be erected at Florence, Alabama.‡

Cost of Pig Iron in North Carolina.—The following is an estimate of the cost, per ton, of making Bessemer pig iron in North Carolina:§—

	Dollars.	Shillings.
Mining, $1\frac{3}{4}$ ton, 60 per cent. ore, at 50 cents per ton	0·83	3·47
Freight, $1\frac{3}{4}$ ton ore, 40 miles, at $\frac{3}{4}$ cent per ton per mile	0·50	2·09
Coke, $1\frac{1}{4}$ ton, at 1·65 dollar f.o.b. at Pocahontas	2·07	8·64
Freight, $1\frac{1}{4}$ ton coke, 245 miles, at $\frac{1}{2}$ cent per ton per mile	1·53	6·39
Limestone, 25 cents; labour, 1 dollar	1·25	5·21
Maintenance, 50 cents; repairs, 50 cents	1·00	4·17
Interest, 25 cents; salaries, 50 cents	0·75	3·13
Total cost per ton of pig iron	7·93	33·10

Cost of Making Pig Iron at Florence, Alabama.—Mr. J. M. Hartman || gives the following estimate of the cost, per ton, of producing pig iron at Florence, Alabama:—

	Dollars.	Shillings.
Coke, 2400 lbs.	2·95	12·16
Ore	3·30	13·39
Limestone	0·50	2·09
Labour	1·50	6·26
Repairs	0·50	2·09
Loss in coke and ore	0·34	1·49
Supplies, taxes, insurance, office, &c.	1·13	4·61
Interest, &c.	0·57	2·39
Total	10·79	44·48

Zinc and Lead in Blast Furnace Gases.—According to Vita,¶ the loss of zinc and lead in Upper Silesia has decreased since the intro-

* *Iron Age*, vol. xliv. p. 882.

† *Ibid.*, p. 1001.

‡ *Ibid.*, p. 1002.

§ *Ibid.*, vol. xlv. p. 289.

|| *Ibid.*, p. 173.

¶ *Zeitschrift für angewandte Chemie*, 1890, p. 69.

duction of the gas-cleaning apparatus attached to the Cowper stoves. It is, however, impossible to recover all the zinc and lead contained in the charge. Experiment shows that the waste gases of one blast furnace carry 27 per cent. of the zinc contained in the charge, and 9·2 per cent. of the lead.

The Manufacture of Ferro-Manganese.—The blast furnace method for the manufacture of ferro-manganese was first introduced at the Sava and Jauerburg Works, in Upper Carniola.* At these works the manganese ore smelted was derived from the Vigunschiza mines, and contained, as a maximum, less than 30 per cent. of manganese, the chemical composition being approximately as follows:—

Mn.	Fe.	CaO.	MgO.	Al ₂ O ₃ .	SiO ₂ .	S.	P.	Cu.
31·3	6·3	7·1	1·8	0·7	18·1	trace	0·04	0·00

This ore was sometimes roasted before being charged into the blast furnace. It was smelted in admixture with spathic iron of two kinds, one being richer in manganese than the other. The following is a partial analysis of the ore containing the smaller percentage of manganese:—

Fe.	Mn.	CaO.	Insoluble Residue.
46·9	1·1	10·6	11·3

The mixture was smelted at Sava in a blast furnace about 44 feet high by 10 feet in diameter at the boshes. The main difficulty consisted in obtaining a sufficiently hot blast, as only some small iron stoves were available. The fuel was the best boxwood charcoal, and to increase the fluidity of the very basic slag produced, fluor-spar was added to the furnace charge. The following are some analyses of the slag:—

	MnO.	CaO.	FeO.	Al ₂ O ₃ .	SiO ₂ .
1	19·66	21·56	1·44	21·39	33·46
2	23·95	19·66	3·84	8·19	41·37
3	27·00	18·85	1·30	14·04	37·45
4	30·28	16·41	1·25	14·94	35·57

The production diminished with the increase in the percentage of manganese from 57·5 tons per week of a metal containing 10 per cent. of manganese to 28·1 tons with 42·4 per cent. of manganese.

* *Stahl und Eisen*, vol. x, pp. 422–423.

Moisture in the Blast.—Mr. S. D. Mills* calls attention to the necessity of using the driest air possible for supplying blast furnaces. In December 1888 he found that the saturation or dew-point in the engine-house was 75° F., and the air consequently contained 0·00131 lbs. of water per cubic foot. The external temperature at the time was 10° F., so that an icicle had formed at a leak in the hot-blast stove where the moist air escaped. Each lb. of water requires 6892·4 heat units to decompose it, while each lb. of fuel in burning to carbonic oxide yields 4000 units, so that 1·72 lbs. of carbon are required for the dissociation of the steam. If the external air at 10° F. had been used instead of saturated air at 75°, there would be a saving from this cause of 11·16 bushels of charcoal per ton. The author therefore suggests that the buildings and engines should be arranged so as to take air directly from the exterior, whatever the weather, in preference to using the air in the buildings.

It is suggested that the presence of water vapour in the blast not only reduces the temperature in the furnace, but also oxidises the silicon in the iron, and thereby tends to make it of harder grade. The value of water vapour as a conveyer of heat from the stove to the furnace seems, however, to require consideration.

A Modified Cup-and-Cone.—A modified cup-and-cone charging apparatus is described in *Stahl und Eisen*.† It is provided with a central take-off for the escaping gases, and an arrangement by which the whole charge may be tipped in at one operation, the charging truck revolving around the cup on a circular track of rails during the charging. The apparatus is in use at the Anina Works, Hungary.

Improved Cowper Stoves.—M. Boecker gives drawings of the improved Cowper hot-blast stoves recently erected at Friedenshütte, Germany.‡ These stoves are three in number, and have each a heating surface of 48,439 square feet. They supply the blast for two blast furnaces, each using 120 tons of coke per day. The blast is raised to a temperature of 800° C.

New American Hot-Blast Stoves.—A number of stoves of the Massicks and Crooke type are being erected in the Southern and other

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 306-310.

† Vol. ix. p. 992.

‡ *Stahl und Eisen*, vol. ix. p. 920.

portions of the United States. The dimensions of some of these are as follows: *—

Locality.	Diameter.		Height.	
	Ft.	In.	Ft.	In.
South St. Louis	17	0	60	0
Paducah	16	6	63	0
Youngstown	19	6	65	0
Bellaire	18	0	65	0
Roanoke	18	0	65	0
Birmingham	16	6	62	0

Two 22 by 65 feet Ford-Moncur hot-blast stoves were recently erected at the Emma Furnace of the Union Rolling Mill Company, at Cleveland, Ohio. The blast furnace is 16 feet in diameter at the boshes and 75 feet high. The main blast pressure is 7 lbs., and the average temperature of blast at the tuyeres 1400° F., though 1500° and even more can easily be attained. With the temperature at 1400° and one stove blown continuously for two hours, the average decline in temperature has proved to be 180°, and never more than 200°.†

II.—CHEMICAL COMPOSITION OF PIG IRON.

Basic Pig Iron.—The following are analyses of the pig iron used for the basic process at Ilsede and in the Moselle district.‡

	Ilsede.	Moselle.
	Per cent.	Per cent.
Carbon	3·220	3·00 to 3·50
Silicon	0·108	0·35 to 0·40
Manganese	2·380	1·80 to 2·00
Phosphorus	2·920	2·00 to 2·25
Sulphur	0·049	?

Phosphorus in Cast Iron.—The action of phosphorus on cast iron has been studied by Mr. W. J. Keep§ with the aid of Keep's tests. Phosphorus produces a peculiar effect on the grain, so that each grain

* *Iron Age*, vol. xlv. p. 1001.

† *Ibid.*, p. 466.

‡ *Stahl und Eisen*, vol. x. p. 47.

§ *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

is apparently independent of the others, and the metal has a white or straw colour. No influence is exerted to change combined carbon to graphite, or *vice versa*. When the carbon is nearly all combined, there is but little effect on the grain, and when silicon is deficient, there is a tendency to a lamellar fracture. Phosphorus lessens the tendency to form blowholes, because the iron remains fluid longer even when low silicon would tend to render the castings porous. There seems to be no effect on the chill, but shrinkage is lessened. No element weakens cast iron so much as phosphorus, but in quantities less than 1·5 per cent. its influence in this direction is not so great as to overbalance the beneficial effect which is exerted before the percentage reaches 1 per cent. Under impact and transverse breaking tests the iron bends more in proportion to the weight borne before breaking. Permanent set decreases as phosphorus increases. Under certain conditions silicon exerts a softening influence, and phosphorus does not ordinarily harden iron, for the reason that it does not increase the combined carbon. The phosphorus appears to increase the fluidity to only a slight degree, but it causes the metal to remain longer in a fluid state, which property is quite distinct from the readiness to flow well. As a rule, the foundry irons most sought after contain about 1 per cent. of phosphorus. Silicon irons, which are used as foundry softeners, often contain 1 or 2 per cent. of phosphorus, so that much of their effect may be ascribed to the latter element. One-half to one per cent. of phosphorus will, however, do all that can be done beneficially. A large number of tables, diagrams, and illustrations are given by the author.

Aluminium in Cast Iron.—Mr. W. J. Keep* substantiates the statements previously† made by him in reference to the influence of aluminium on cast iron, and presents the chemical analyses of the test-bars. The last section of the paper is devoted to a discussion of the use of ferro-aluminium in foundry practice. Aluminium in cast iron changes combined carbon into graphite without the weakening effects that silicon produces, but the introduction of the alloy into molten cast iron is difficult. Small fragments of the alloy are generally melted if they are placed in the ladle before the iron is run in, but if the ferro-aluminium is thrown into the melted iron, it chills the metal and will not melt. Pure aluminium, when thrown on the surface, melts at

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

† *Journal of the Iron and Steel Institute*, 1888, No. II., pp. 300-301.

once, but it does not thoroughly alloy with the iron, as the castings are coated with a film of the metal. Aluminium, when introduced into the ladle, causes the metal to boil, probably on account of the liberation of the graphite. This ebullition is so rapid that slag is carried down into the metal, and, moreover, the slag is rendered so tender that it is difficult to pour the iron without patches of the slag breaking away and flowing into the mould. The ferro-aluminium may be introduced with the charge of pig iron into the cupola, but a better method remains to be found. It would be well if it could be introduced into the metal like silicon in the blast furnace. Its use is desirable when iron without chilling tendencies is sought. It is to white iron or iron low in silicon that it should be added, and not to grey irons. Iron is greyer, stronger, and softer if aluminium is used instead of silicon. It is then especially suitable for thin castings.

Foundry Pig Iron made from Swedish Iron Ores.—According to Lundström,* foundry pig iron must be easily fusible, so as to be adapted for fine castings. This property, as is well known, is increased by phosphorus, an element usually absent from Swedish ores. For many years, however, lake and bog iron ores have been used in South Sweden for the manufacture in small quantities of a metal of great fluidity when molten. In former years this industry was very considerable, as more than 12,550 tons were annually produced. Now, the production has sunk to 2090 tons annually. This decrease, however, is due solely to the low price of pig iron, and in no way to the want of ore supplies.

It is thus a question whether a pig iron could not be produced containing the same percentage of graphite, silicon, and phosphorus as the English product. This question, the author believes, should be answered in the affirmative in so far as the Southern and Central portions of Sweden are concerned. The phosphoretted magnetites occurring there would of course require to be smelted with a silicious charge and very hot blast in coke blast furnaces.

American Foundry Iron.—The Chickies Iron Company, Pennsylvania, gives the following analysis of the No. 1 foundry pig iron produced by the Company:—

Graphitic Carbon.	Combined Carbon.	Silicon.	Sulphur.	Manganese.	Phosphorus.
3·140	0·269	2·260	0·013	0·484	0·321

* *Wermländska Annaler*, 1889; *Berg- und Hüttenmännische Zeitung*, vol. xlix. p. 87.

This is stated to be an average analysis of this brand of iron. The ore used is a brown hæmatite.*

III.—BLAST FURNACE SLAGS.

Fayalite Crystals in Slag.—K. Kozirowski † has observed well-developed crystals of fayalite in a mill cinder from the Koschiki Iron-works, near Warsaw. On analysis, they yielded 31·69 per cent. of silica and 67·78 per cent. of ferrous oxide. Under the microscope numerous inclusions of magnetite were observed.

The Utilisation of Blast Furnace Slag.—More than nine years ago, Mr. C. Wood contributed to the Society of Arts a paper on the utilisation of slag. The chief methods that have been brought forward since the reading of that paper are fully discussed by Mr. G. Redgrave.‡ Mr. Wood introduced many ingenious methods for dealing with slag, and of these the various processes for utilising molten slag by casting it into blocks, the production of slag sand, and the preparation of bricks and mortar from this sand are the most important. In recent times the casting of blocks has made important progress under the Tees Scoriæ Brick Company, chiefly in the production of granatine paving setts, in which the cleaved rough surface of the slag brick is exposed to wear instead of the smooth polished surface. These blocks, being non-porous, are very durable, and at Middlesbrough a road surface exposed to heavy traffic for eleven years is still in good repair.

The annealed slag has also a strong affinity for Portland cement, and this fact has been turned to practical account by the Jones's Annealed Concrete Company, of Middlesbrough, who employ this material for paving purposes. Broken slag is also in use in various parts of the country for road-making. Slag-wool or silicate cotton, also originally obtained by Mr. Wood, is a further important application of blast-furnace slag. It is obtained by causing a jet of steam to impinge upon the stream of molten slag as it issues from the furnace, and has the following properties:—(1) It is extremely light and is absolutely fireproof; (2) it is a good non-conductor of heat and of sound; and (3) it is so porous that it absorbs large quantities of water, which

* *Bulletin of the American Iron and Steel Association*, vol. xxiv. p. 47.

† *Warszawskija Uniwersitetskija Izwjestija*, vol. i. pp. 1-9; *Zeitschrift für Krystallographie und Mineralogie*, vol. xvii. pp. 527-528.

‡ *Journal of the Society of Arts*, vol. xxxviii. pp. 221-234.

it readily retains for a considerable time. The slag-wool is, moreover, an antiseptic, and is being used for medical purposes. Large quantities of cement are also now made from slag sand, without the addition of Portland cement, by mixing it with 25 per cent. of lime. In order to ensure a successful cement, the mixture is ground in a machine of special construction termed a "homogeniser." The specific gravity of this cement is very low as compared with Portland cement, while the time occupied in setting is comparatively long. For purposes of storage it also compares well with Portland cement. By exposure to the air it absorbs carbonic anhydride more rapidly than Portland cement does, but it does not deteriorate greatly in tensile strength by long exposure.

The author gives the following results of tensile tests:—

Derivation of Slags Made into Cements.	How Kept.	1:3 Sand.				Neat Cement.			
		7 Days.	28 Days.	3 Months.	12 Months.	7 Days.	28 Days.	3 Months.	12 Months.
South Wales	Water	280	314	430	500	582	697	...	...
	Air.	230	327	...	...	...	...	...	...
Middlesbrough	Water	328	470	482	375	405	416	...	...
	Air.	253	263	430	529	...	...	...	...
Skinningrove	Water	320	440	447	483	506	564	...	...
	Air.	247	322	...	...	...	...	...	...
Brunswick	Water	350	420	...	...	410	523	...	...
Osnabrück	Water	214	420	...	...	...	...	...	...
	Water	405	630	725	...	350	410	440	...
Nancy	Air.	420	495	...	...	...	...	...	...
	Sea-water	380	510	600	...	400	430	510	...
Portland cement	Water	...	62	132	161	558	674	815	825
German cement	Water	274	364	...	...	...	...	...	...

For works in water, owing to the closeness of its particles, the cement appears to be particularly well adapted. Crushed slag can be used as concrete with this cement for making sea-walls. It has been in use abroad for many years, but the system of cement-testing in England has militated against its having a fair trial in this country. In Germany, used alone or mixed with Portland cement, it is held in great favour. The author gave an outline of the utilisation of basic Bessemer slag as a manure, and pointed out the astonishing rapidity with which this fertiliser has been introduced into German agriculture, where it has exceeded the total available native production of the slag, giving rise to a large import from this country and Austria. He concluded by urging the English farmer to follow the example set in Germany, as, at its present price, basic Bessemer slag-meal can be

obtained in this country at about half the cost of superphosphate. He added that it seemed sad that we should be importing phosphates from America in large quantities, and exporting a good home-made phosphate to the Continent.

Mr. Bennett H. Brough * describes a method in which blast furnace slag may in many cases be advantageously utilised. This consists in filling in block slag into the worked-out excavations in collieries, so as to support the superincumbent strata. In this way considerable economy has been effected in a number of German collieries, notably at the Gräfin Lauria pit in Upper Silesia, where a large amount of coal had formerly to be left to support the surface, as the workings are directly under the town of Königshütte. The slag is lowered into the workings by a self-acting incline from the adjacent ironworks, the cost of transporting the slag, and of stowing it in the workings, amounting to about 6d. per ton.

Whatever may be the way in which the slag is utilised, the question of finding an economical method of transport is of great importance. Such a method is in use at a number of ironworks in the Siegen district, Westphalia. The slag runs from the blast furnace into a channel of rapidly flowing water, which granulates it into fine sand and carries it to a large iron tank, from which it is automatically charged into the buckets of an Otto aerial wire-rope tramway. It is then transported to a waste heap at a considerable distance from the works.

Manufacture of Slag Cement.—The manufacture of slag cement has of recent years acquired so considerable a development, that it may safely be said that an advantageous method of utilising blast furnace slag has at length been found. At the present time there are numerous works in England, in France (Saulines, Marnaval, Haute-Marne), in Switzerland (Choindez), in Germany (Thale, Düsseldorf, Wetzlar, Neunkirchen, Laurahütte), where the slag is converted into cement, the quality of which, it is true, is very variable, but when carefully made it undoubtedly possesses valuable properties. An exhaustive memoir on the manufacture of this material has been prepared by J. Grosclaude.† In this he gives the following table of analyses of slags actually used for the manufacture of cement :—

* *Journal of the Society of Arts*, vol. xxxviii. p. 332.

† *Annales Industrielles*, 1889, pp. 90, 206, 270; *Dingler's Polytechnisches Journal*, vol. cclxxv. pp. 433-445.

	Marnaval.	Saulines.	Choindex.	Hartzburg.	Middlesbrough.	Bilbao.
Lime . . .	48·00	47·20	45·11	48·59	32·26	47·30
Silica . . .	30·50	31·65	26·88	30·72	31·65	32·90
Alumina . . .	19·50	17·00	24·12	16·40	25·30	13·25
Ferrous oxide . .	0·85	0·65	0·44	0·43	0·10	0·46
Magnesium oxide	0·75	1·36	1·09	1·28	3·54	1·37
Calcium sulphide	...	...	1·86	2·16	1·42	3·42
Manganese oxide	0·40	0·85	0·50	trace	0·36	1·13
Loss . . .	...	1·29	...	0·42	5·37	0·17
Totals . . .	100·00	100·00	100·00	100·00	100·00	100·00

The author gives an estimate of the cost of a factory to produce 20 tons daily or 6000 tons annually of slag cement. The operations that have to be conducted are—(1) granulating the slag; (2) drying the slag sand; (3) slaking the lime; (4) screening the lime; (5) grinding and mixing the slag sand and slaked lime.

The apparatus required is as follows:—

	France.
Ruelle dessicator	14,000
Four edge-runners	9,200
Four pairs of grindstones	4,000
Accessories for mills	1,300
Two ball-mills	5,000
Seven automatic weighing machines	1,750
A centrifugal screener for lime	2,200
Five elevators	4,000
An archimedean screw	400
Shafting, &c.	9,000
A 150 horse-power engine	30,000
Boiler and stack	18,000
Cost of erection	25,000
	<hr/> 123,850 *

Including the expense of sacks, barrels, means of transport, &c., the total cost may be estimated at 150,000 francs, or £6000.

Utilisation of Slag for Evaporating.—Sir Lowthian Bell † has devised a process for utilising the waste heat of slag for evaporating brine and other solutions. The slag from iron or other furnaces is received into iron vessels, mounted on wheels, and capable of containing several tons. These vessels, when charged, are passed down an incline into a chamber over which an evaporating pan of large area

* 119,850 in original.

† *Journal of the Society of Chemical Industry*, vol. ix. p. 67.

is set. When the slag blocks are in the chamber, they are sprinkled with water to harden the exterior. Steam is thereby generated, and comes into contact with the bottom of the pan, or may be passed through pipes immersed in the solution in order to heat the brine. Water, contained in the lower part of the chamber, is reached by the slag waggons as they progress slowly down the incline, and accordingly is heated to the boiling-point for the further generation of steam. When the slag is sufficiently cooled, the waggons are run up a second incline and out of the chamber.

In place of using water, a current of air may be caused to circulate continuously through the chamber in an opposite direction to the travel of the slag blocks, and under the evaporating pans.

Slag as Railway Ballast.—In discussing railway track, Mr. E. E. R. Trotman * gives several opinions on the use of slag as ballast. As a rule, no pitting or corrosion of the rails or metal sleepers have been noticed, though several kinds of slag have been used. Mr. W. C. Irwin states that white oak sleepers thus laid do not last so long by two years as they do in gravel.

The Use of Fluor-Spar in the Metallurgy of Iron.—Dr. Foehrt discusses the possible use, on a large scale, in the future, of fluor-spar in the metallurgy of iron. Its use as a solvent and fuel-saving ingredient is most marked, and in the manufacture of ferro-silicon its use is almost a necessity. Similarly, in the manufacture of ferro-manganese and spiegeleisen, it tends greatly to increase the ease of the reduction.

IV.—*FOUNDRY PRACTICE.*

The Whiting Cupola.—Attention is drawn to the satisfactory results obtained with the Whiting cupola. At the works of the Detroit Car Wheel Company four such cupolas are in use, and with one of them, having a shell $6\frac{1}{2}$ feet in diameter, there were melted, without re-lining, in the six months ending January 1, 1890, 13,416 tons of iron. The three other cupolas showed equally good results.†

* *Transactions of the American Institute of Civil Engineers*, vol. xxii. pp. 147, 148, and 190, 191.

† *Chemiker Zeitung*, vol. xiv. p. 253.

‡ *Iron Age*, vol. xlv. p. 223.

Cast Iron.—In a paper on cast iron, and its treatment for artistic purposes, Mr. W. R. Lethaby * mentions several art castings in London and other places. There appears to be no evidence that casting iron was practised here before the Middle Ages, nor at what time it was then introduced. M. Viollet-le-Duc supposes that it was known in France in the thirteenth century. In the fourteenth century cast iron artillery was probably founded all over Europe. Cast iron grave slabs from the fifteenth century, fire-backs and other ornamental castings of early and later date, are also described and illustrated. Reference is made to the Sussex iron trade in the reign of Queen Elizabeth. The use of cast iron for architectural purposes is dealt with, and also its use for ornaments, such as vases, &c., with particular mention of castings from Japan. The appearance of cast iron also depends on the treatment of the surface; rusting, galvanising, oxidising, and electro-bronzing are all available for the purpose of ornament.

Ferro-Silicon for Foundry Use.—An exhaustive series of experiments have been made with ferro-silicon by C. Jüngst † at the Gleiwitz Ironworks, in Upper Silesia, with a view to render the Continental iron-foundries independent of the English and Scotch pig iron markets, and to furnish the required material at a cheaper rate. Gautier is of opinion, it will be remembered, ‡ that the Scotch pig iron owes its principal qualities to the presence of silicon. By very numerous experiments in an Ibrügger cupola, Jüngst answers the following questions:—

(1.) Are the views of Gautier and other investigators as to the action of silicon accurate?

Silicon forms a dense cast iron, and it is found that ferro-silicon can be successfully used without difficulty when merely the approximate chemical composition of the material to be melted is known.

(2.) To what extent is the application of ferro-silicon advisable in Germany for the preparation of castings of various kinds?

In addition to the chemical composition of the cast iron, the texture has great influence on the tenacity. This may be obtained both by melting grey pig irons and by melting with ferro-silicon. The employment of grey pig iron is attended with considerable uncertainty. This is obviated when white pig iron and ferro-silicon are employed. It follows that the usual German practice of making castings that must

* *Journal of the Society of Arts*, vol. xxxviii. pp. 272-284.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxviii. p. 1.

‡ *Journal of the Iron and Steel Institute*, 1888, No. I., p. 58.

1890.—i.

possess great tenacity, by melting together grey pig irons, is not advisable. The latter method is preferable both from a pecuniary and a technical point of view, in that white pig iron is cheaper than grey. With the high price of ferro-silicon still prevailing, the employment of grey pig iron for ordinary castings is at the present time, however, preferable on account of its cheapness.

(3.) What percentage of silicon is to be preferred in the ferro-manganese?

At Gleiwitz the best results were obtained by the employment of ferro-silicon with 10·38 per cent. of silicon. With 5·22 per cent. of silicon high tenacities were obtained; but the cast iron was unsatisfactory in other respects, on account of the high percentage of manganese in the ferro-silicon, and on account of the necessity of adding a considerable quantity, so as to increase the requisite amount of free silicon. A material with 14·32 per cent. of silicon acts very powerfully, but at the same time there is the danger that with the small quantity added the action of the silicon is merely local if the molten metal is not properly stirred.

(4.) What is the action of foreign elements in the pig iron on the manganese, phosphorus, and sulphur?

A proportion of manganese and phosphorus amounting to 1 per cent., and a proportion of sulphur amounting to 0·16 per cent. in the cast iron, has no detrimental influence on the product. In charging the materials, however, care should be taken not to exceed these limits.

The results of the author's experiments, which are accompanied by analyses, tensile tests, curves, and numerous illustrations, tend to prove that further study of the properties of silicon and of the related element, aluminium, will show that castings adapted for all classes of work may be made in good quality from purely German material.

Professor A. Ledebur * discusses Jüngst's paper on the use of ferro-silicon for foundry purposes. Jüngst refers to the historical evidence as to the use of silicon, pointing out that Bischof in 1847 published the results of experiments which showed that the addition of silicon to white pig iron led to the formation of a perfectly grey iron, and counteracted the influence of manganese. The author refers to the other papers relating to this subject which have since been published by other authors, and the conclusions to which they led are also passed in review—conclusions which have already been given in the preceding volumes of this Journal.

* *Stahl und Eisen*, vol. x. pp. 292-299.

Jüngst points out that the relative degree of hardness and the tensile strength of cast iron are not dependent merely on the chemical composition of the metal, but also to a considerable degree on its texture. This texture, Ledebur observes, is in its turn dependent on the mode of cooling, apart from the chemical composition. With regard to the latter question, the author has himself found small quantities of a number of elements, not generally determined analytically, to exist occasionally in foundry iron; such, for instance, as titanium, vanadium, and chromium. Arsenic and antimony are frequently found, and the spectrum of the Bessemer flame leads to the inference that alkali metals, as well as metals of the alkaline earths, are also occasionally present in the metal. These impurities undoubtedly exert some influence, and if the quantities of each of them are in themselves too small to affect the character of the metal appreciably, yet taken together they may sometimes exert considerable influence.

A Casting Flask.—A folding casting flask is illustrated in the *American Manufacturer*.* The sides are made of hard wood one inch thick, and can be folded down flat for storage. The parts are made by machinery, so that they are interchangeable, and one or more copes or drags can be used together. An adjustable clamp which dispenses with wedges is also shown.

Casting Mortars.—The Builders' Iron Foundry, Providence, have made nearly thirty 12-inch mortars for the United States Government. They are made of a cast iron body, hooped with two rows of steel bands. Each mortar is 11 feet in length over all, and has a weight of $15\frac{1}{4}$ tons, the contract price being £261. The method of casting is as follows:—

The mould in which the cannon is formed is placed in a flask set in a brick well or pit some 20 feet deep. This flask is about 18 feet long, and is composed of six sections, which are clamped firmly together. Each section consists of about an inch of iron and 10 inches of clay lining, which has been baked hard. A cylindrical wooden mould pattern, 33 inches in diameter, is placed upon a platform inside the flask. The soft clay is then pressed down and the pattern is removed, the flask containing the soft coating of clay being taken to the oven and baked. When all the sections of the flask have been thoroughly baked, they are clamped firmly together. The core consists of a hollow

* Vol. xlv. No. 14.

and fluted iron tube, wound on the outside with rope, and covered with a layer of clay 1 inch thick, having a diameter of 11 inches.

After the iron has been melted, the top of the flask is removed and the metal is run in. A fire has previously been placed in the bottom of the pit in order to thoroughly heat the outside of the flask. Between the flask and the furnace is placed a swivel basin, through which the molten iron passes towards the flask. In less than ten minutes the flask is full; the top is then replaced.

The core is kept cool by a water supply pipe, which runs from the top to the bottom through the centre, while the heated water is removed through an escape valve in the top of the core bar. The rapidity of the cooling of the metal is regulated by the temperature of the water at the outlet and the rate of flow into the jacket. These temperatures are determined every hour.

In about twenty-four hours the mass is cool and solid enough to permit of the removal of the core, and then the water is turned directly into the gun itself. This cold-water core is the essential feature, and was the invention of General Rodman.*

Casting Plates in Open Sand Moulds.—B. Platz † discusses the casting of plates with flat surfaces in open sand moulds. The iron for such a casting should contain from 1.2 to 1.5 per cent. of silicon, and 3.0 to 3.5 per cent. of carbon. Such a metal gives a clean flat surface, and is of considerable strength and toughness. Plates cast in open moulds, however, irrespective of the quality of metal, will rise in the centre, if arrangements are not made to allow the steam from the damp sand to escape without forcing up the metal. This may be done by making a coke-bed below the sand of the mould. By the aid of suitably placed tubes, the steam may then be readily withdrawn.

Drying Furnace for Foundries.—W. Uge ‡ describes a drying furnace for foundry purposes. The firing—arranged either for gas or solid fuel—is external, and the furnace is continuous in action. Two illustrations accompany the description.

The Piat Crucible Furnace.—J. H. Constant Steffen § describes with the aid of several illustrations the Piat furnace for foundry purposes. This furnace is swung on trunnions, the crucible in which the

* *Iron Age*, vol. xlv. p. 139.

† *Stahl und Eisen*, vol. x. p. 228.

‡ *Stahl und Eisen*, vol. x. p. 277.

§ *Ibid.*, pp. 189-194.

fusion is to take place being fixed in the furnace in such a manner that it need not be removed during the casting, which is effected by simply turning the furnace down, the metal running from the crucible over a spout attached to the furnace. The air being forced into the furnace under considerable pressure, very rapid fusion and high temperatures may be readily attained, combined with a considerable saving in fuel. In a modified form of this furnace no crucible is used, the furnace itself acting as a miniature cupola.

Sand Blast for Cleaning Castings.—An illustration is given by *Industries** of an apparatus which has been designed by a Sheffield company for cleaning castings by means of a sand blast. Decided advantages have been found in using the sand blast for cleaning ornamental and cored castings where there are a great many hidden surfaces, on account of the rebounding of the grains of sand in all directions. The slightly roughened surface which the blast produces is well adapted for the adherence of zinc and plating metals. It has been found that the action of the blast does not interfere with the quality of the metal. In working with this apparatus, the casting is introduced through a door at the back, and the workman places his hands through the two oblong openings in the front, and thus holds the article. A glass window is arranged above the holes for him to look through to see the progress of the operation. Larger castings are supported by a chain, and are simply guided by the workman.

* Vol. viii. p. 128. Compare *Journal of the Iron and Steel Institute*, 1889, No. II., p. 444.

PRODUCTION OF MALLEABLE IRON.

The Future of the Direct Process.—In his treatise on the metallurgy of iron and steel, Mr. H. M. Howe * thinks that there is but little reason to suppose that the direct process will be profitably applied to lean ores, but that there is hope of producing iron with less fuel but with greater labour than in the blast furnace in the case of richer ores. The balling processes seem to promise most, such as the American bloomary, the high bloomary (*e.g.*, Husgafvel's), and the Eames process. This class gets rid of the gangue at once, delivers hot balls for the open-hearth, and dephosphorises the metal. The failure of the direct process has not been so complete as is generally believed; many failures have occurred, but as knowledge increases, so will the process develop, like the evolution of the blast furnace. The most promising feature for the process is the use of natural gas owing to its great cheapness. The author proceeds to give a classification or general scheme of the direct processes. In the first class, the ore is reduced and heated by the same solid fuel in charcoal hearths and in shaft furnaces. In the second division, ore is reduced and heated by the same gas in a shaft furnace or retort. The third class includes those processes in which the ore is reduced by solid fuel, and heated by other than the reducing fuel; this class is subdivided into those methods which include reduction in retorts, shaft furnaces, &c., and into those in which the reduction is performed in open reverberatories. These last two classes may again be subdivided into steel-melting heat, balling, and sponge-making processes; in the first class the product is balled.

The problems to be solved seem to be :—

1. The application of natural gas in some shaft like Husgafvel's.
2. Better means of removing the balls than in Husgafvel's process.
3. Some quick cheap way of cooling the sponge for sponge-making processes.

* *Engineering and Mining Journal*, vol. xlviii, pp. 259-269.

4. An automatic compressing apparatus for sponge, so simple that a single mechanic can compress enormous quantities rapidly.
5. Some cheap way of desulphurising producer gas.

Conley-Lancaster Direct Reduction Process.—A plant for the direct reduction of iron ore is illustrated in the *American Manufacturer*.^{*} Magnetic sand or similar ore is treated by magnetic separation, and is then fed into iron retorts protected by fire-clay slabs. The ore is mixed with carbonaceous matter, or is reduced by gas which is led through the retorts, which can be heated by gas or other fuel. Mechanical stirrers are used to stir up the material in the retorts. The reduced ore is transferred direct to an open-hearth furnace, with as little exposure to air as possible. This is effected by means of a shoot which covers the mouth of the retort, and guides the sponge into a receptacle which is raised and run over the charging door of the furnace. This method is adopted in place of mixing the sponge with pitch, as previously described.[†] Calculations of the cost are also given.

Explosions in Puddling Furnaces.—An investigation relating to a fatal accident at a German works, resulting from the destruction of a puddling furnace by explosion, has proved that the explosion was a double one. It took place during the cooling stage, and is believed to have been due, in the first place, to a sudden evolution of steam. This slight explosion produced a partial vacuum, which became filled with an explosive mixture of gas and air, thus giving rise to the second and much more violent explosion. Various suggestions are made as to the precautions that should be taken in the use of water for cooling the furnace.[‡]

The Puddling Process in France.—In 1877 there were in existence in France 955 puddling furnaces making iron and 51 making steel.[§] The annual production of the former amounted to 821,006 tons, and of the latter to 20,273 tons. In 1887 the number making iron had fallen to 637, with a production of 617,997 tons, and to 35 making steel, with an out-turn of 12,532 tons. The puddling process, therefore, still holds its own to a very great extent. In the Department

^{*} Vol. xlv. No. 7.

[†] *Journal of the Iron and Steel Institute*, 1888, No. II., p. 253, and 1889, No. I., p. 328.

[‡] *Stahl und Eisen*, vol. x. pp. 205-208.

[§] *Ibid.*, vol. ix. p. 909.

of Meurthe and Moselle there are double furnaces having a capacity of five tons. Mechanical puddling is but very little employed, though there are some works in the Department just mentioned at which it is in use. A Pernot furnace is in use at the Chamond Works, and some rotating furnaces on the Bouvard system are stated to be employed at the Creuzot Works.

Puddling for steel is employed at a few works in the Loire district, such as the Alleward Steelworks and those of Messrs. J. Holtzer & Co., where the pig iron from their charcoal furnaces is converted into puddled steel. The process is also adopted at some of the larger works, amongst which are the Aciéries de la Marine et des Chemins de Fer at St. Chamond, and the Chatillon and Commentry Works.

Puddling Furnaces at the Bethlehem Works.—At the South Bethlehem Ironworks, Pennsylvania, there are three double-double, four double, and one single puddling furnace, with boilers over the furnaces. The mill has recently been used for the production of muck-bar exceedingly low in phosphorus, which is used for remelting in the open-hearth furnaces for the production of steel of high quality necessary for ordnance and shafting work.*

* *Proceedings of the United States Naval Institute*, vol. xv. No. 4.

FORGE AND MILL MACHINERY.

Rolling-Mill Appliances.—A plan and elevation is published in the *Iron Age** of a roller appliance, designed by H. Aiken, of Pittsburg, for the purpose of enabling the slabs, plates, &c., to be easily transferred from one portion to another of the mill plant, scales being so arranged that the mill products may be transferred to the weighing platform by a movement either of the scales or of the rollers. The weighing of the mill product at different stages of the treatment is thus greatly facilitated.

The Lanth Three-High Rolls.—In these rolls the middle one is of smaller dimensions than the other two, this design being based upon the principle that, in consequence of wedge-like action, rolls of small diameter extend metal to a relatively greater extent than do larger rolls. By making the centre roll smaller than either of the other two, the mill has a greater capacity than would be the case if all three rolls had the same diameter. It has been proposed to use these rolls for making sheets, but it is pointed out that their use is not advisable if very thin sheets are to be produced.†

Rolling-Mill at East Chicago, Indiana.—The new rolling-mill of the National Forge and Iron Company occupies a building which measures 360 by 140 feet, with a wing 100 by 50 feet, having additional projections for housing shears to cut scrap and for storing the different kinds of materials used. There are three trains of rolls—an 18-inch train for bars, a 10-inch for guide iron, and an 18-inch train for muck-bar. Four double heating furnaces are provided for the finishing-rolls, and four double puddling furnaces supply the muck-mill. The rolls are driven by a 40 by 48 engine and a 20 by 30 engine. There are seven shears, designed especially for the work

* Vol. xlv. p. 130.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 63-68.

required, and all driven by separate engines. The largest shear is capable of cutting 5-inch rounds cold, and is said to be the largest in Western America. It is to be used for cutting scrap, such as waggon axles, &c. The large number of shears is occasioned by the intended use of scrap as the chief raw material, but provision is made for puddling if it proves desirable to use pig iron. The furnaces are designed for the use of oil-fuel, the intention being to use no coal. Steam is supplied by nine boilers, all attached to the furnaces so as to utilise waste heat.*

New Rolling-Mill in Alabama.—The first steel blooming-mill hitherto erected in the Southern United States is about to be laid down at Fort Payne, Alabama. It is a 32-inch mill of modern type, and includes two 38 by 48 reversing engines. A 22-inch nail-train and a 16-inch bar-train, together with a 9-inch guide-train and a large ingot shear to cut up to 7 by 10 inches, are also to be erected at the same works.†

Housing Gear for Rolling-Mills.—Hitherto the manipulation of the large housing screws for adjusting the upper roll of rolling-mills has usually necessitated the employment of four men, two to each screw. By means of the gear devised by Mr. S. Jardine,‡ this manipulation can be easily performed by one man. The action of the gear is very simple. A shaft is driven continuously from any convenient source, and carries at either end a pair of mitre wheels, which run loose. Either wheel of these pairs may be driven at will by means of a special form of clutch, which slides upon a feather in the shaft, and is actuated by a conveniently placed hand-lever. A third mitre wheel on either side, and deriving motion from the wheels, actuates worms, which in turn transmit motion to the screws by means of worm wheels. The screws are also provided at their upper extremities with graduated brass index rings, by the aid of which a delicate adjustment can be effected. It is claimed that by the sensitive action of the clutches employed, the screws can be rapidly manipulated with the greatest nicety, that the slab is worked much quicker than by hand-screwing, and that consequently the risk of breakage is reduced to a minimum.

The Jardine screw gear for rolling-mills has been in work for a

* *Iron Age*, vol. xlv. p. 403.

† *Ibid.*, p. 1001.

‡ *Industries*, vol. viii. p. 458, three illustrations.

considerable time at the plate rolling-mill of Messrs. David Colville and Sons.*

Rolling Rails.—According to Mr. D. K. Nicholson,† the essential feature in rolling steel rails is to have all the passes exactly filled, if the passes are properly turned out. If the bar does not fill out to any pass, more stuff is put in by enlarging the previous passes or by moving the rolls apart. If the bar is too large in cross section to roll out in length, there is a tendency to fin, or the extra metal will shear off. Side guards are used to guide the rail, and are also used to force the piece over, and so to put more metal on one side or the other. A small fin, or its indication, is the only sign that the metal has filled the pass properly. The wedge-like shape of the flange gives a considerable end thrust to the rolls, and must be met by sufficient force, or else the rail will be higher on one side than the other, and will have a thick and a thin flange. The over-filling of the head is the greatest trouble in rolling, and this can only be remedied by re-turning the rolls. Since the head of the rail is made somewhat rounding, the two rolls must be parted at the middle of the head in the finishing pass. A larger angle under the head gives more scope for the turner in the leading pass, and consequently less trouble in the finishing pass. No fixed rule can be given for the draught, but 10 to 20 per cent. will cover all cases when the piece is turned to receive work on all sides. In breaking down, light draught tends to make the sides concave, and the work is confined to the surface. The hotter the work the greater the tendency to go out in length, while in colder rolling there is a greater tendency to fin. More spread may be expected in high than in low carbon or mild steel. When the train of rolls is not strong enough, the rolls may be strengthened by increasing their diameter, shortening them, or by using better material. Rolls of small diameter are more likely to work out flaws. Short rolls would appear to be preferable, as they have less spring. Cast steel rolls crack badly on the surface, whilst forged steel rolls are preferable except for their cost. In three-high rolls the top passes can be altered without disturbing the lower ones. A two-high mill has the advantage in handling the work, and in there being only two rolls. But then all the passes are affected by shifting one roll, except the finishing pass is in another housing.

* *The Engineer*, vol. lxi., two illustrations.

† *Transactions of the American Society of Mechanical Engineers*, through *The Engineering and Mining Journal*, vol. xlviii. pp. 472-473.

The speed of a two-high reversing mill affects the proper formation of the rail. The importance, when rolling long lengths, of good bearings all in line is also mentioned.

Mill - Engine.—A triple expansion mill-engine is illustrated in *Industries*.* There are four cylinders arranged in pairs, so as to form two complete vertical tandem-engines. The two lower cylinders form the low pressure, and above them are the high and intermediate pressure cylinders. The high-pressure cylinder is 16 inches in diameter, the intermediate 25 inches, and the others are each 28 inches. The stroke is $3\frac{1}{2}$ feet. Corliss valve-gear is used. Power is transmitted by an 18-foot pulley grooved for twenty-two ropes, $1\frac{1}{2}$ inch in diameter.

Toggle-Joint Drawing-Press.—The Stiles & Parker Press Company, Connecticut, have designed a new toggle-action drawing-press. The working parts are symmetrical in design, front and back views of the machine being identical in appearance. It has hitherto been customary in such presses for the blank-holder to be forced down, holding the metal while it is being drawn by the direct action of the cams. In the new press the blank-holder slide receives its movement from four powerful direct-acting toggles, which, in turn, receive their motion directly from the main shaft. The upper links of the toggles are slotted, and in these slots are steel rollers, which are connected with a cross-head, and thence through the connecting rods to the main shaft. During the first quarter of a revolution the cross-head moves down, so as to bring the rollers upon the straight surfaces of the upper links, thus bringing the toggle links to a straight line and the blank-holder slide down upon the work to be held. For the next half of the revolution the rollers pass down the plain surfaces and back without exerting any power upon the links, leaving the blank-holder slide at rest. This perfect rest of the blank-holder slide during this half of the revolution is a most essential feature, as it gives a uniform and constant pressure upon the work, and prevents any wrinkling of the blank while being drawn. During the last quarter of the revolution the blank-holder slide rises, so that when the press comes to rest, the blank-holder slide has overtaken the drawing-plunger, giving all the room necessary for the removal of the finished work.

The toggle trunnions are set into the frame of the press, thereby throwing all the strain from the blank-holder slide directly upon one

* Vol. viii. pp. 123-125, illustrations.

frame, instead of upon the main shaft bearings, as in the case of the cam-press.

The adjustment of the blank-holder is obtained by four large screws passing through long bearings in the upper end of the slide, and held in place by check-nuts having broad faces, which, combined with the long bearings, give a rigidity to the slide otherwise unattainable.*

Rail-Straightening Press.—A press of this type, designed by Messrs. W. Todd & Co. for the Edgar-Thomson Steelworks, is illustrated in the *Iron Age*.† The press is of simple construction, and a number of them are now in use. The shafts are of steel, the pinion being forged on the driving shaft and cut out of the solid.

Sheet-Metal Drawing-Press.—All machines of this class contain three essential features: (1) a hollow die, whose inside form is that of the article to be drawn; (2) a punch, which enters the other die and presses into it the metal under treatment; and (3) a metallic ring, which surrounds the punch and presses the sheet of metal or “blank” against the flat face of the hollow die, from between which two surfaces the blank is drawn as the punch strikes it and carries it into the die. Illustrations have appeared of a large machine of this type.‡

* *Iron Age*, vol. xlv. p. 45, one illustration.

† Vol. xlv. p. 332.

‡ *Ibid.*, vol. xlv. pp. 1-3, four illustrations.

PRODUCTION OF STEEL.

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I.—*THE OPEN-HEARTH PROCESS.*

Progress of the Open-Hearth Process.—F. W. Lürmann * refers to the rapid progress that has been made by this process in recent years. The author has recently examined fifty-two patents relating to the process, and gives a summary of their contents. He divides the patents into several classes:—(1.) Proposals for the introduction of an air-blast into the molten metal on the hearth; (2.) others relating to the direct reduction of iron from its ores without the use of the blast furnace; and (3.) proposals for the dephosphorisation of pig iron. The author also discusses generally the question of the use of ore in the furnace, as well as the dephosphorisation on the basic hearth.

The more important patents in each class are referred to in considerable detail, and the author remarks generally upon their value. A valuable epitome is also given of the facts relating to the rise and progress of the basic open-hearth process, and the numerous other methods that have been suggested for the dephosphorisation are also mentioned. With reference to the use of iron ore as an addition to the molten bath, the author sketches historically the various published statements relating to it, and in conclusion draws attention to the preference given to the use of basic open-hearths at the Resicza Works, notwithstanding the fact that the pig iron used is well suited to the acid Bessemer process, containing as it does only from 0·062 to 0·070 per cent. phosphorus.

* *Stahl und Eisen*, vol. x. pp. 10–18 and 194–205.

The Use of Ore in the Open-Hearth Process.—The furnace in which E. G. Odelstjerna* carried out a series of experiments held charges of 4·5 tons. For 25 charges A-ores (Bisperg) were employed, for 45 charges B-ores (Timansberg), and for only 9 operations D-ores (Åsgrufve). All the charges with A-ores yielded an iron with less than 0·1 per cent. of carbon; the operations with B-ores, however, gave in 16 cases iron with 0·1 per cent. and less of carbon, in 16 cases iron with 0·2 per cent. of carbon, and in 13 cases steel with 0·9 per cent. of carbon; whilst the 9 operations with D-ores gave an iron with 0·15 per cent. of carbon.

Three kinds of pig iron were employed. No. 1 contained 6·204 per cent. of impurities, No. 2 not more than 5·670 per cent., whilst No. 3 contained as much as 8·448 per cent.

The A-ores required per charge an average period of 10 hours 50 minutes. Altogether, 68 tons of No. 1 pig iron, 4·5 tons of No. 2, and 31·6 tons of No. 3, or a total of 104·1 tons were treated; and in each operation 22·22 lbs. of ferro-manganese, containing 80 per cent. of manganese and 13 per cent. of iron, and 165·88 lbs. of A-ores were added. The product consisted of 102·970 tons of blooms and waste, or of 9061·8 lbs. of metal per charge.

The metal charged was as follows:—63·781 tons with No. 1 pig iron, 4·145 tons with No. 2, 29·022 tons with No. 3, and 7·26 lbs. with the ferro-manganese; altogether 96·981 tons. The product contained—

[Manganese.	Carbon.	Silicon.	Phosphorus.	Sulphur.
0·25	0·10	0·02	0·032	0·015

A total of 0·417 per cent. of impurities. The product amounted to 102·541 tons of iron. Thus from the ore charged 102·541 – 96·981 = 5·560 tons were reduced. As the proportion of iron in the ore amounted to 53 per cent., 56·1 per cent. of the total proportion of iron was obtained.

From the B-ores, with 59 per cent. of iron, only 29·7 per cent. was obtained in the production of metal with 0·20 per cent. of carbon. The behaviour of these ores in the production of steel with 0·9 per cent. of carbon was quite different, as much as 62·7 per cent. of the proportion of iron being reduced.

Lastly, the D-ores, with 56·5 per cent. of iron, gave 54·1 per cent. of that proportion in the production of iron with 0·15 per cent. of carbon.

* *Jernkontorets Annaler*, vol. xliv. pp. 332-340.

The following table shows the amount of time, of ferro-manganese, and of ore required per ton of pig iron charged :—

Ores.	Percentage of C. in Product.	Pig Iron Charged.	Per Ton (1000 kg.) Pig Iron.				
			Consumed.			Product.	Yield from Whole Charge per 1000 Kg.
			Time.	Ferro-Manganese.	Ore.		
		Kg.	Min.	Kg.	Kg.	Kg.	Kg.
A-ore . . .	0·1	4164	156	2·42	179	989·2	959·6
B-ore . . .	0·1	3938	165	2·39	162	962·4	934·3
D-ore . . .	0·15	4290	150	3·63	203	998·8	949·9
B-ore . . .	0·2	3758	167	3·56	161	963·5	934·6
B-ore . . .	0·9	3547	157	0·99	146	986·8	968·1

Thus the loss in the case of iron amounts to 4·04 to 6·57 per cent., and in the case of steel to not more than 3·19. The production of the latter consequently appears to be the cheaper. The metal from the pig iron is worth at least $3\frac{1}{2}$ times as much as that from the ores, and therefore a fair loss on the ore open-hearth process represents much less money than in the scrap open-hearth process.

Basic Open-Hearth Process at the Kladno Works.—At the Kladno Steelworks, Bohemia, C. Stöckl * states that the charge for the basic open-hearths—soft bridge metal being produced—consists of 3 tons of highly phosphoric pig iron and 10 tons of scrap, mostly very low in carbon. Unburnt lime is added in quantities varying up to half a ton, the evolution of the carbonic anhydride assisting to stir up the bath. The melting-down takes about five hours, and in half an hour or an hour from 130 to 260 lbs. of ferro-manganese is added. The soft low-carbon metal produced in this manner has been greatly used in Austria for construction purposes.

The Latrobe Steelworks, Pennsylvania.—At these new works two 15-ton open-hearth furnaces have been erected. Each furnace has its own ladle-crane and four 7-ton pit-cranes of the Aiken hydraulic type, all operated from one pulpit. A 20-ton and a 7-ton steam-hammer have been erected, as well as a tyre-mill and machine-shop.†

Styrian Open-Hearth Steel.—Some further notes on Styrian

* *Stahl und Eisen*, vol. x. p. 21.

† *Iron Age*, vol. xlv. p. 958.

open-hearth steel are supplied by Mr. F. Korb and Mr. T. Turner.* The supply of fuel in Styria is limited. Lignite occurs, but is very impure, so that the production of steel is necessarily limited. Most of the Styrian tool-steel is exported, partly as crucible steel, partly as raw steel, described previously. The puddled steel contains:—

C.	Si.	P.	S.	Mn.	Ni & Co.	Cu.
0·76	0·048	0·019	0·002	0·18	0·003	0·005

and the open-hearth raw steel is of almost equal purity. But though this steel is equal in purity to crucible steel, yet it cannot be produced with a high percentage of carbon without retaining its impurities. Consequently the Styrians can only produce a hard or middling hard steel.

The authors lay stress on the fact that the purity of the crucible steel depends on the purity of the raw steel used in its manufacture, as the impurities cannot be reduced, but only increased by crucible melting. The remelting only renders the steel homogeneous. It is claimed that Styrian steel can be welded even when it contains 1 per cent. of carbon, owing to its purity, which also causes it to stand the action of the fire well. For remelting steel, either clay or graphite crucibles may be used. Clay pots are specially suitable for mild steel, as they do not carburise the metal. In Styria, and on the Continent generally, plumbago pots are used. The irregularity of carburisation due to successive meltings in the same crucible is then pointed out, and an analysis is given of graphite from Kaisersberg.

The Use of Magnesite for Basic Linings.—N. Kjellberg † discusses the results of a journey in which he inspected basic open-hearth furnaces erected in Germany, Austria-Hungary, and France. In no works that he visited did he find either dolomite or lime used wholly by itself for basic linings; neither did he find chrome iron ore used alone for this purpose. Frequently a mixture of lime and dolomite with magnesite was employed; sometimes, too, though much less frequently, a mixture of chrome iron ore and magnesite was employed, with or without the addition of lime; and dolomite or magnesite in larger or less quantity was in use at nearly every works. At those works in which it is used alone without other additions, it is employed both in the form of bricks and as stamping material, the hearth being usually made of the

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, November 27, 1889, *Iron*, vol. xxxv. pp. 71-73; compare *Journal of the Iron and Steel Institute*, 1889, No. I. p. 343.

† *Jernkontorets Annaler*, vol. xlv. pp. 389-466, No. 7.

latter, and the fire-bridge and walls of the bricks. In one instance, however, bricks alone were used, and in another stamping material alone. The most important deposits of magnesite are in Styria, where a hill of considerable size consists wholly of this substance. The following are analyses of this magnesite, both in its natural state and after burning :—

	MgO.	CaO.	Mn ₂ O ₃ .	Fe ₂ O ₃ .	Al ₂ O ₃ .	Insoluble Matter.	Loss on Ignition.
1.	42.43	1.68	0.53	3.53	0.03	0.92	50.41
2.	84.26	2.25	0.72	8.40	2.50	0.50	1.30

1. Unburnt; 2. Burnt.

Another sample of a calcined magnesite showed :—

MgO.	CaO.	Mn ₂ O ₄ .	Fe ₂ O ₃ .	Al ₂ O ₃ .	SiO ₂ .	CO ₂ .
72.67	16.49	0.44	3.46	0.08	5.11	0.13

The magnesite is treated similarly to lime or dolomite, that is to say, it is calcined sweet, broken down, and ground, then mixed with a binding material and formed into bricks. Unlike dolomite and lime, however, it may remain exposed to atmospheric action for an indefinite period without being subject to deterioration.

In making dolomite bricks, boiled tar is usually employed as the binding material, although burnt or unburnt dolomite and water have been employed for that purpose. At the Diosgyör Works in Hungary no tar is used, the material being prepared in the following manner :— After being ground to such a degree of fineness that it will pass through a sieve with a 0.08-inch mesh, it is spread out on the floor of the works, and is brought to a plastic state by mixing with a sufficient quantity of dolomite-milk, this latter being prepared by well mixing partly calcined dolomite with water. Instead of dolomite, milk of lime may be employed.

The basic portion of an open-hearth furnace consists of the hearth, the fire-bridge, and the walls of the laboratory portion, the latter being sometimes only basic for a portion of their height. Occasionally, too, the gas and air ducts are also made of basic material.

The hearth, in by far the greater number of the works visited, was constructed partly of magnesite bricks and partly of a stamped mass of dolomite or lime; a stamped bed resting on a brick underlay lasting much longer than when the bed is stamped right through without any bricks being used. In order to save cost, it is customary to make the lower layer of acid bricks, a layer of magnesite bricks resting upon these, and intervening between them and the stamped lining. If, however, the stamped mass consists wholly of magnesite, it is of course

unnecessary to employ any basic bricks at all. With regard to the number of supporting layers of brick, it is usual to regulate the thickness of the bed in such a manner that near the tap-hole it is supported by a thickness of two bricks, and at the opposite wall by a thickness of four bricks. When these brick-layers are dry, the basic bed is stamped down, either with tar or some other binding substance.

The fire-bridge is always made of basic material. In most cases it consists of a core made of magnesite bricks resting directly upon the cooling-plate, against which the hearth is stamped.

When dolomite or lime is the main basic material employed, it must be kept out of contact with the acid walls by an intervening layer of magnesite or chrome iron ore. This layer should in no place be less than 1 or 2 inches in thickness. The walls are always made of basic material to a height above the point which the boiling slag may reach when the hearth is full. Some works make the walls of basic material up to the roof, whilst others only make them basic to the level of the fire-bridge.

At every works visited the tap-hole was always made of magnesite bricks, even when stamped dolomite or lime was employed for the bed of the furnace. The method of producing this stamped bed is described, the author giving as an example the method of lining an 11-ton furnace.

As a mortar, powdered sifted magnesite is employed, the size of the particles not exceeding 0.08 inch in diameter, together with tar or milk of dolomite or lime as previously mentioned, or with water alone. Sometimes even dry magnesite powder is used alone without any addition.

The percentage of tar used as a binding material varies enormously. At one works it was only sufficient to give a dark colour to the mixture, whilst at another works the mixture of tar and magnesite was quite fluid. The tap-hole is stopped up with a mixture of tar, magnesite, dolomite, or lime, sand being used on the outside. At one of the works visited, magnesite was employed for this purpose with clay as the binding material.

The author draws special attention to the success of the furnaces at Diosgyör, where no tar is used, dolomite milk being the sole binding material. Chrome ore was formerly used at these works, but it has now been almost completely abandoned in favour of magnesite. The author draws a comparison between the various basic materials, much in favour of magnesite.

II.—THE BESSEMER PROCESS.

The Nischnje-Saldinsk Steelworks.—Dr. F. C. G. Müller* discusses a description by a Polish engineer, Grum-Grgimaila, which appeared in the Russian *Gorny Journal*. In this paper details are given of the Bessemer process as carried out at the Nischnje-Saldinsk Steelworks in the Ural. At these works three large elliptical charcoal blast furnaces treat ore from a neighbouring mine; the composition of this ore is as follows:—

Fe_2O_3 .	FeO.	MnO.	Al_2O_3 .	CaO.	MgO.	SiO_2 .	Cu.	P.
75.40	16.71	1.30	1.80	0.99	0.98	2.85	0.06	0.03

together with a trace of sulphur.

The ore is smelted direct without fluxes, the quantity of slag formed being only 20 per cent. When cold blast is used, the pig iron produced contains only 0.2 to 0.3 per cent. of silicon; with blast of a temperature of 200°C . the percentage of silicon reaches 0.6; and even when the blast is raised to 550° , the furnace working very hot, yields iron containing only 0.9 per cent. To obtain a pig iron suitable for the Bessemer process, silicious additions have, therefore, to be made, and the charge in recent years has consisted of 85.6 per cent. ore, 6.2 per cent. slag from the heating furnaces, 3.3 per cent. manganese ore, and 4.9 per cent. sand.

Each of the three furnaces produces, with a blast temperature of 540°C . and a fuel consumption of 1.1 ton of charcoal for each ton of iron, 18 tons of pig per twenty-four hours. The quantity of slag is only 30 per cent. in spite of the additions. The furnace is very sensitive, and the silicon contents of the iron fluctuate in the most unaccountable manner between 0.8 per cent. and 2.5 per cent.

The direct process could not be considered on account of these fluctuations in the composition of the pig iron. It was cast into pigs, and after grading was melted in an open-hearth furnace. As soon as the charge was melted it was run into the converter.

An accident led to the substitution of this ordinary method of conducting the Bessemer process by a new method. The accident in question made it necessary to keep the pig iron in the Siemens furnace for $1\frac{1}{2}$ hour, the result being such a large loss of silicon that the sample became white iron. It was feared that the charge would chill in the converter, but, much to the surprise of the managers, the blow was very hot from the commencement, and rail ends had to be added at the

* *Stahl und Eisen*, vol. x. pp. 115-119.

close to cool it down. The reason for this unexpected result was the high initial temperature, the iron as it flowed from the Siemens furnace into the converter having been at a white heat. The experiment was repeated with the best results, and it was shown that iron with only 0·8 per cent. of silicon could be converted, provided it was run into the vessel in a very hot condition.

Another consideration led to the decision to work with superheated iron containing only 0·8 per cent. of silicon. The rail-mill connected with the works makes not less than 25 to 30 per cent. of scrap, for which there is not a ready market. It was therefore decided to melt the scrap with the pig iron in the open-hearth, producing a metal containing 0·8 per cent. of silicon. The pig iron is tapped directly into a ladle and poured into the Siemens furnace. The fracture of a sample shows to the experienced eye of the melter approximately the silicon contents, and he gauges by it the necessary addition of scrap. In the case of deep grey iron this reaches 40 per cent. The open-hearth acts as a regulator in adjusting the fluctuations in the working of the blast furnace, and also places under the control of the blower the initial temperature for the Bessemer process. This important function of the Siemens furnace is supplemented by that of utilising all the scrap.

The consumption of fuel in the open-hearth furnace is chiefly required to melt the scrap. Of the heat which the pig iron brings with it from the blast furnace nothing is lost, because the silicon and the manganese which enter the slag in the open-hearth yield their heat of combustion to the bath of iron. Finally, it must be taken into consideration that through the additions of scrap to the bath the percentage of carbon in the metal is reduced, which in turn leads to a considerable shortening of the blow in the converter.

Two series of analyses are given, which indicate the reactions in the open-hearth furnace and in the converter. One charge consisted of 2·56 tons of pig iron and 1·28 ton of rail ends. The mixture before entering the open-hearth contained 3·06 per cent. of carbon, 1·31 per cent. of silicon, and 2·28 per cent. of manganese. When tapped, it contained 2·28 per cent. of carbon, 1·18 per cent. of silicon, and 1·72 per cent. of manganese.

The second charge consisted of 3·48 tons of white iron, without any addition of scrap. Before charging into the open-hearth it contained 3·70 per cent. of carbon, 0·75 per cent. of silicon, and 2·60 per cent. of manganese. When tapped, analysis showed 3·65 per cent. of carbon, 0·70 per cent. of silicon, and 2·01 per cent. of manganese.

This charge certainly remained a shorter time in the furnace than did the first charge, since no scrap had to be melted. Still, as the cost of the subsequent blow in the Bessemer converter showed, it was tapped at a considerably higher temperature than was the first charge, probably at about 1500° C. Both charges yielded a hot blow in the converter, so that at the close of the blowing 0·368 ton of rail ends was added to the former, and 0·112 ton to the latter. The following series of analyses indicate the nature of the blow in the converter :—

	Carbon.	Silicon.	Manganese.
<i>First Charge—</i>	Per cent.	Per cent.	Per cent.
Pig iron . . .	2·28	1·18	1·72
After 4 minutes .	1·34	0·68	1·12
After 8 minutes .	0·70	0·35	0·80
After 12 minutes .	0·28	0·02	0·12
<i>Second Charge—</i>			
Pig iron . . .	3·65	0·70	2·01
After 3 minutes .	2·50	0·56	1·31
After 6 minutes .	1·70	0·47	1·29
After 9 minutes .	1·05	0·43	1·04
After 12 minutes .	0·55	0·33	0·65
After 14½ minutes .	0·28	0·03	0·31

In conclusion, the author refers to the evident commercial value of imparting a high temperature to the iron before charging it into the converter; and he points out how readily this temperature of charging might be attained in practice.

Steel from the Longwy Works.—The daily out-turn of steel at the Longwy Works, France, is from 250 to 300 tons. The following table shows the composition of the several classes :—

	Designation.	Hardening Power.	Carbon.	Phosphorus.	Manganese.	Tensile Strength.	Elongation.
			Per cent.	Per cent.	Per cent.	Tons per square inch.	Per cent.
1.	Hard	Hardens well	0·30-0·35	0·08-0·10	1·0-1·20	47·6-44·4	12-14
2.	"	"	0·26-0·30	" "	0·85-1·00	44·4-41·3	14-16
3.	Semi-hard	Hardens "	0·22-0·26	" "	0·70-0·85	41·3-38·1	16-18
4.	"	"	0·18-0·22	" "	0·60-0·70	38·1-34·9	18-20
5.	" Soft "	Scarcely hardens	0·15-0·18	" "	0·50-0·60	34·9-31·8	20-22
6.	"	"	0·10-0·15	" "	0·40-0·50	31·8-29·2	22-24
7.	Very soft	Does not harden	0·09-0·10	" "	0·25-0·40	29·2-26·7	24-26
8.	Extra soft	" "	0·08-0·09	0·05-0·08	0·20-0·25	26·7-24·1	26-28

Only a trace of sulphur is found in the steel. *

* *Stahl und Eisen*, vol. ix. p. 910.

Bessemer Shop at the Bethlehem Steelworks, Pennsylvania.

—According to Mr. W. H. Jaques,* this shop is 1512 feet in length, and contains four 7-ton converters, arranged in a straight line across one end of the mill, and surrounded by an iron platform supported on cast iron columns. Behind them are the iron and spiegeleisen cupolas; they are supplied with double platforms, one above the other, commonly called the charging and tapping floors. These floors communicate with the converter platform and with each other by means of iron stairs. Three converters are worked in succession, while one is off for repairs; the iron cupolas are run four on and four off; the spiegeleisen cupolas are run two on and two off. This method of working facilitates repairs and prevents the necessity of any excessive repairing or protracted delays. The converters have wrought iron shells, 8 feet in diameter; the body is completely lined with blocks of mica schist, roughly hewn to shape, and the nose is lined with firebrick. These linings are so durable that each is considered good for 30,000 tons of ingots, and in the old plant, on one occasion 54,000 tons were made on the lining of two converters, without the removal of any blocks except those in the nose, and a few at the bottom joint. The converter bottoms have 17 firebrick tuyeres, each with twelve $\frac{3}{8}$ -inch holes. Between the tuyeres, bricks are set on end like the blast furnace lining bricks, and as close together as possible, the interstices being rammed with ordinary gannister bottom stuff. To dry this bottom four hours is sufficient; it will stand from twelve to fourteen heats. The output of the converter plant is 4000 tons per week of eleven shifts. The heats of ingots are from 7 to 8 tons according to the weight of the rail. Fourteen-inch ingots are bloomed down to 7 inches square, and are then cut into single and double rail-blooms for the rail-mill.

There are two Bessemer blowing-engines of the following dimensions: The smaller has two steam-cylinders 36 by 60 inches, coupled direct with two air cylinders 48 by 60 inches, which are placed behind the steam-cylinders and on the same bed-plate; the steam-cylinders are coupled on their forward end through cross-heads and connecting rods to a fly-wheel shaft, whose cranks stand at right angles. The larger engine has two steam-cylinders 56 by 66 inches, and two blowing cylinders 60 by 66 inches, arranged like the smaller ones. The large blowing-engine running with 50 lbs. of steam is capable of maintaining a blast pressure of 40 lbs. of air. The cupola blast is obtained from

* *Proceedings of the United States Naval Institute*, vol. xv. No. 4.

four No. 7½ Baker blowers, coupled direct to the shaft of a compound engine running at 90 revolutions.

The blast pressure at the blowers is about 1¼ lb., and 11 oz. at the tuyeres. Another compound engine directly coupled with four blowing cylinders is kept in reserve for the cupolas. A Worthington duplex and two Worthington compound duplex pumps are also situated in this transept, and supply a water pressure of 300 lbs. to the square inch.

The converter-bottom repair shop is situated in the upper end of the mill, and is furnished with hydraulic cranes for handling, and ovens for drying. At this end of the mill, a brick foundry has been erected on the south side and adjoins the mill. This foundry is used for the manufacture of ingot moulds, the consumption being six to eight per day. The equipment consists of a cupola and two power cranes. In the main portion of the mill, just below the pits and handling floor, are six Siemens reheating furnaces. Three furnaces are placed on either side, with hydraulic cranes for charging and drawing the ingots. Centrally, between these furnaces and under command of the hydraulic cranes, run two narrow-gauge tracks, one running to the casting-pits, the other to the blooming-train. There are two blooming-mills, two engines, and three sets of rolls. The smaller engine is 36 by 60 inches, coupled direct to two sets of three-high 32-inch rolls. Both sets are supplied with tables driven by power and controlled by two levers at one point. The large mill is also three-high; the rolls are 48 inches in diameter and 10 feet long; the engine is 65 inches by 8 feet, with a 90-ton fly-wheel. This mill is similar to the smaller one, but handles a larger ingot. From the blooming-mill the ingot passes to steam-hammers, is cut into rail-blooms, and charged into the rail-mill heating furnaces.

These furnaces (four in number) are similar in construction to the blooming-mill furnaces, varying only in size, and are situated immediately below the blooming-mill. The rail-mill consists of three sets of rolls. The engine is a vertical compound one, with 36-inch high-pressure and 56-inch low-pressure cylinders, 50-inch stroke; the rolls are 24 inches, three-high. The rail passes from the rolls to the hot saws, and thence to automatic hot straighteners, hot beds, cold straighteners, drill presses, and then to a line of driven rollers, which carry the rails to the trucks for shipment. A new 28-inch mill rolls heavy sections and long lengths. This train is driven by three high-speed compound engines on one shaft, connected with the middle roll and driving direct. The aggregate power of these engines is 8000 horsepower. The necessary tables are of novel design, and are worked auto-

matically by water or air. In the heating furnaces of this department, a gas made from crude petroleum oil is used for fuel at the present time, instead of coal-gas made in Siemens producers, as was originally the case. The annual output of the works amounts to about 250,000 tons of rail-blooms, billets, &c., 3000 workpeople being employed. The works extend for $1\frac{1}{4}$ mile in length by a quarter mile in width, 18 acres being under cover. In the ordnance works the steel is subjected to fluid compression treatment. The open-hearths have a casting capacity equal to 100 tons of ingots. This portion of the works is supplied with a 125-ton single-acting steam-hammer, and extremely powerful hydraulic forging presses.

The Basic Bessemer Process at the Kladno Works.—C. Stöckl* describes the basic Bessemer process as carried out at the Kladno Works, Bohemia. The time required for the decarburisation is about eight minutes, the point being ascertained by the disappearance of the green carbon lines in the spectrum. The after-blow lasts from four to five minutes. About 90 to 130 lbs. of ferro-manganese containing from 80 per cent. of manganese is then added, and the molten bath allowed to rest for six or eight minutes. The reaction is not violent. The addition of spiegeleisen takes place after the metal has been poured into the ladle and most of the slag removed. A violent reaction then ensues. For the same brand of pig iron the same percentage of spiegeleisen is always added, and for soft metal this usually amounts to about 0·13 ton for a charge of 13 tons (12 tons pig iron and 1 ton scrap). The spiegeleisen contains about 10 per cent. of manganese. Samples are taken at the beginning of the cast and towards its end, and these form the test-pieces for the welding and red-short tests. Hard material for rails, &c., is marked S; semi-hard metal, T; and soft varieties, such as boiler-plate, B.

A nearly uniform product is obtained, as will be seen from the following analyses of successive charges :—

No. of Charge.	Carbon.	Phosphorus.	Manganese.
27,255	0·07	0·047	0·107
27,256	0·08	0·057	0·217
27,257	0·08	0·023	0·126
27,258	0·07	0·051	0·229
27,259	0·08	0·018	0·143

* *Stahl und Eisen*, vol. x. p. 21.

The Oldest Small Bessemer Plant.—At Turrach a small Bessemer plant has been working uninterruptedly since 1863.* At the present time the usual charge is 2·2 tons. The smallest charge amounts to 15 cwt.

The Robert-Bessemer Steel Process.—Mr. T. W. Robinson † describes the Robert-Bessemer steel process as carried on at the works of Messrs. Burgess, and also at the Stenay Works, Paris. The pig iron used at Paris is a No. 2 Bessemer, and is melted in a cupola with a fuel consumption of 1 lb. of coke to 6 lbs. of iron. The converter in use is acid lined, and has a capacity of one ton; it is blown with a pressure of 6 lbs. through five slightly-converging horizontal tuyeres, and is turned by hand. About 1 to 1½ per cent. of ferro-silicon is used with the ferro-manganese, the former containing manganese 5·13, silicon 12·10, and the latter manganese 66·0, and carbon 5·70.

The following is an analysis of the steel produced :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
0·142	0·150	0·053	0·048	0·860

The metal is used for castings, and the results are very satisfactory.

At the Stenay Works the pig iron used in the basic process contains from 0·42 to 1·40 per cent. of silicon, 1·77 to 2·07 per cent. of phosphorus, and 0·0 to 1·20 per cent. of manganese.

The converter lining is made of calcined dolomite and tar, the blast is blown through six 1½-inch horizontal tuyeres, the charge of metal is 1900 lbs.; about 7 per cent. of lime is added before, and an equal quantity during the blow. For mill-stock no ferro-silicon is used. Only 1 to 1½ per cent. of 70 per cent. ferro-manganese is added in recarburising. Including about 3 per cent. in the cupola, the loss from pig iron to steel is from 12·8 to 16·1 per cent. The blow lasts about eleven minutes, including the afterblow; the output of two converters amounting to about 35 tons per day. Some analyses of the steel produced gave :—

Carbon.	Silicon.	Phosphorus.	Manganesec.
0·08	...	0·019	0·30
0·12	0·009	0·065	0·40
...	0·000	0·051	0·86

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 98.

† *Iron Age*, vol. xlv. p. 674.

The pig iron used for the acid process contains from 1·1 to 2 per cent. of silicon and about 1·2 per cent. of manganese. A sample of the steel produced showed :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
0·270	0·257	0·051	0·070	1·000

The following are the results of tests of metal that was used for gun-carriages for the French navy :—

Test.	Tensile Strength. Pounds per Square Inch.	Elongation per Cent.	Number of Blows.	Analysis.		
				Carbon.	Silicon.	Manganese.
1.	74,123	28	14	0·225	0·150	1·0
2.	70,132	28·2	24	0·240	0·070	0·7
3.	99,068	7	6	0·250	0·127	1·0
4.	75,548	24	12 (did not break)	0·250	0·190	1·1

The falling-weight test is made by dropping a 40-lb. weight on a bar $1\frac{3}{8}$ inch square, set on supports $6\frac{3}{8}$ inches apart, from a height of 39 inches, increasing the height of fall 37·4 inches at each blow. Twelve blows are adopted as the standard, all failures below being rejected.

The Solubility of Basic Slag.—E. Jensch* has tested the solubility of basic slag with a view to ascertain the degree of solubility of the phosphoric acid in slags containing very different percentages of it. Citric and oxalic acids dissolved nearly the whole of the phosphate without any marked difference being observed between slags rich in phosphorus and those containing relatively little. The presence of silica in the slag diminishes the solubility of the phosphoric acid ; magnesia, on the other hand, increases it.

Basic Slag for Manure.—At the Creuzot Works, France, the slag from the basic Bessemer process is ground for agricultural purposes, and contains from 12 to 18 per cent. of phosphoric anhydride and about 45 per cent. of lime. The following is an analysis : †—

P ₂ O ₅ .	CaO.	MgO.	FeO.	MnO.	SiO ₂ .	SO ₃ .	Al ₂ O ₃ , &c.
15·98	44·98	5·09	15·22	5·68	10·00	0·12	2·93

* *Zeitschrift für analytische Chemie*, vol. xxviii. p. 299.

† *Stahl und Eisen*, vol. ix. p. 911.

Prof. Dobbie,* of the North Wales University College, Bangor, has just made a report upon a series of elaborate agricultural experiments which have been carried out in connection with the agricultural department of the college upon Derwendeg farm, near Welshpool, Montgomeryshire, in order to test the value of basic slag as manure. The results of the experiments have been carefully tabulated, and the general conclusion arrived at is that basic slag is a valuable form of phosphatic manure for arable, pasture, and meadow land. The author is of opinion that for poor pasture land it is one of the best manures at the command of the farmer.

Grinding Basic Slag.—It will be remembered that a prize was recently competed for at Berlin for a satisfactory method of grinding basic slag with adequate protection from dust to the workmen and the bearings of the machinery employed in the grinding. The prize was divided among three of the competitors :—Messrs. Wasum, of Bochum ; Zimmer, of London ; and Sachsenberg, of Rosslau. Dr. H. Wedding† describes the methods of these inventors, as well as the others which were proposed to meet the difficulties that have been experienced in practice. The basic slag which is ground at the works of Messrs. Stumm—the donors of the prize—in Neunkirchen has the following average composition :—

P_2O_5 .	SiO_2 .	CaO.	MgO.	Fe_2O_3 .	FeO.	MnO.	CaS.
17·23	6·60	53·23	2·50	4·40	10·66	3·40	1·06

The method of grinding that is adopted leads to the formation of large quantities of dust, which, whilst being extremely injurious to the workpeople employed, rapidly wears out the bearing surfaces of the machinery. Great care was taken to adopt suitable methods for preventing the escape of the dust, but without avail. The firm then decided to offer the prize to which reference has just been made. The various methods proposed are described by the author at some length ; but whilst it was decided to divide the prize offered among three of the competing processes, none of them was deemed absolutely satisfactory.

* *Iron and Coal Trades Review*, vol. xl. p. 95.

† *Stahl und Eisen*, vol. x. pp. 310–320.

FURTHER TREATMENT OF IRON AND STEEL.

The Hardening and Tempering of Steel.—The lecture on this subject by Professor Roberts-Austen* delivered before the British Association, contains a comprehensive history of the subject, full references being given to all the works of the writers quoted, from the earliest periods down to the present day. The hardening and tempering of steel are largely the results of the form which the carbon therein is made to assume, but the main facts are not fully explained by the change in the mode of existence of the carbon. Further explanations are forthcoming by the assumption of the existence of allotropic forms of iron. The consideration of this important branch of the subject is entered into at great length, and Osmond's investigations, which have been summarised by that observer in a paper communicated to this Institute since the publication of Professor Roberts-Austen's lecture, are fully described.

Looking back over all the facts dealt with, it is evident that two sets of considerations are of special importance: (1) those which belong to the relations of carbon and iron, and (2) those which contemplate molecular change in the iron itself. The first of these has been deliberately subordinated to the second, although it would have been possible to have written much in support of the view that carburised iron is an alloy of carbon and iron, and to have traced with Guthrie the analogies which alloys, in cooling, present to cooling masses of igneous rocks, such as granite, which, as the temperature of the mass falls, throw off "atomically definite" bodies, leaving behind a fluid mass of indefinite composition, from which the quartz and felspar solidify before the mica. This view has been developed with much ability in relation to carburised iron by Howe, who even suggests mineralogical names, such as "cementite," "parlyte," and "ferrite," for the various associations of carbon and iron.

* *Nature*, 1889, November 7 and 14.

Chemical elements act on each other in accordance with the great law of Mendeléeff, which states that the properties of the elements are periodic functions of their atomic weights. The author firmly believes that it will be shown that the relation between small quantities of elements and the masses in which they are hidden is not at variance with the same law, and he has shown that this is true in the case of gold by examining the effect of small quantities of impurity on the tenacity of the metal.

Hardening Steel and Iron.—Mr. Watson Smith * describes a new process for hardening steel and iron invented by Captain G. Feodosieff. This consists in the employment of glycerine for tempering these materials. The specific gravity of the solution of glycerine may be varied between 1.08 and 1.26 at 15° C., by adding water according to the composition of the steel and the effects desired. Its temperature may also be varied between 15° C. and 200° C., according to the hardness of the metal, it being found advisable to employ a high temperature for hard steels. To increase the quenching power of the bath, various salts may be added to the glycerine solution, manganese or potassium sulphate being added when a hard temper is required, and manganese chloride or potassium chloride for a softer temper. The advantages which the author claims for his method are—(1) the temperature of the aqueous solutions of glycerine may be varied within wide limits, as the boiling-point of pure glycerine is 290° C.; (2) the variation in the quenching power of the solution, by dissolving these salts in the liquid, has a very marked influence on the degree of temper, and renders it possible to treat very different qualities of steel by this method.

Lead-Tempering of Steel.—The Chatillon-Commentry Steel Company have been experimenting with lead-tempering for gun-tubes, projectiles, and armour-plates.† The steel is heated to a red heat and allowed to cool gradually in a bath of molten lead. Elastic limit, breaking stress, and elongation are increased, as shown in the following table:—

* *Journal of the Society of Chemical Industry*, vol. ix. pp. 144-146.

† *Engineering*, vol. xlix. pp. 654-655. Compare *Journal of the Iron and Steel Institute*, 1888, No. II., p. 289.

Carbon per Cent.	Elastic Limit, Tons per Square Inch.		Breaking Stress, Tons per Square Inch.		Percentage Elongation.	
	Untempered.	Tempered.	Untempered.	Tempered.	Untempered.	Tempered.
0·54	...	...	39·36	48·25	15·5	19·5
0·64	...	...	49·08	56·51	10·5	13·0
0·73	24·76	36·82	50·79	60·32	10·0	12·0

Actual tests of an armour-plate, 10·8 inches thick, showed that the penetration in a tempered plate was less than in an untempered one; but the value of this test is lessened by the fact that the gun employed could only send a projectile through 4·85 inches of wrought iron.

Regenerative Annealing Furnace.—A new form of annealing furnace with regenerative firing has been successfully adopted at F. Bösner's wireworks at Augustenthal, near Neuwied on the Rhine.* The furnace has two circular heating chambers or pits, each of which takes a single cast steel annealing pot, which stands on a substructure containing the gas and air passages and regenerators. The latter are low, oblong chambers, measuring 12 by 4 feet and 2 feet high. Two are used to heat the air for each pair of furnaces, and the gas is brought hot from the producer. Above the roof of the regenerator is a mass of brickwork which contains the air and gas flues and the burner, which is a narrow ring-shaped passage, giving a flame that envelops the annealing pot. The chamber is 5 feet high and 4 feet in diameter, and is covered with an iron plate, which also covers the flue which forms a communication between each pair. The chambers are heated alternately, and the spent gases from one chamber pass over the pot in the other and cool it down. Each double furnace heats 10 pots, or a total weight of 8 to 9 tons in ten hours. The pot weighs 18 cwt., and contains 16 to 18 cwt. of hard-drawn wire. The consumption of fuel has been reduced from 12½ to 13 per cent. of the weight of wire heated to 7 to 9 per cent., thus giving an average saving of 36 per cent. of fuel. The wear of the pots has been increased from 300 up to 600 heats, and the labour has decreased as the pots are drawn at a lower temperature. The author gives a design of a similar furnace for reheating steel ingots, and considers that it might be used for cementation furnaces and for making malleable castings.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. p. 477.

Supporting Wire during Annealing.—C. E. Matteson* has designed a simple arrangement for supporting wire during annealing, which has been for some time in successful use at the works of the Iowa Barb Wire Company, Pennsylvania. By its aid the coils or bundles of wire may be readily taken out of or placed in the annealing pot and kept in position without coming in contact with the sides, the annealing being thus rendered more uniform.

Electric Welding.—The application of electricity to welding, stamping, and other cognate purposes is described by Sir F. Bramwell,† who gives an account of the results obtained from an experimental plant. Wrought iron and mild steel are practically the only metals which have been welded before the application of electricity. Simple hammering, screw, and finally hydraulic pressure have been used to make the joints good. Probably imperfect welds are not mostly due to inadequate power or imperfect heating, but to the presence of some foreign body between the surfaces to be welded. Several arrangements are used to avoid the use of welds, as, for instance, in links for suspension bridges, when the ends are often upset to form the eyes. Scarf, birdsmouth, single and double wedge, and butt welds have all been used under various forms, so as to exclude dirt as much as possible. Among the desiderata for welding purposes are, that the mode adopted shall be one admitting of uniform heating throughout the sectional area to be welded; that shall admit of absolute regulation of the heat; that shall be free from the possibility of introducing either particles of fuel or gases between the welding surfaces, and shall also admit of complete inspection during the time that welding is going on. All these desiderata are afforded by electric welding.

Any apparatus intended to utilise the heating effect of the electric current must employ a large current of low pressure, not high pressure and small current. Further, the conductor in which the heat is generated should be of medium conductivity. Iron holds this position between nickel and silver. The resistance of iron increases with the temperature, and this fact explains the uniform heating at the junction of two bars. The roughnesses only at first are in contact; these become heated, softened, and accordingly the pressure brings a larger but cooler area in contact, and a larger part of the current tends to pass through the cooler parts, so that they get heated more rapidly

* *Iron Age*, vol. xlv. p. 293, three illustrations.

† *Proceedings of the Institution of Civil Engineers*, vol. cii.

than the parts which are already hot. Having regard to this, it is not possible to say what number of amperes should be sent through a bar to raise it to welding temperature, as time has to be taken into account, and also the effects of radiation and conduction.

As large currents at low pressure have to be transmitted, the conductors must be short and as large in section as possible, in order to prevent their heating and the consequent loss of power. For these reasons the welding machine and the dynamo are often designed as one structure. Another method is to develop high-tension currents, which are transformed at the welding machine by suitable transformers into low-tension currents of large quantity. The transformer consists of a hollow cylinder built up of discs of wrought iron, insulated with paper, and wound longitudinally with the high-tension current conductor. A hollow copper core is placed inside the cylinder, and is connected to the clamps which hold the bars to be welded.

The plant temporarily erected by the author consisted of a two-cylinder portable engine, three dynamos giving 5000, 20,000, and 40,000 watts at 1398, 1340, and 973 revolutions per minute respectively, and three different types of welders. The steam-cylinders were $9\frac{1}{2}$ inches diameter by 14 inches stroke, and the steam pressure 80 lbs., giving 115 revolutions when the current was partly on. A test was made with the large dynamo and welder on pieces of Farnley round iron $1\frac{1}{2}$ inch in diameter. Eighty welds were made in three hours thirty-nine minutes, including a rest of half an hour. The gross indicated horse-power throughout the trial was 33·1, and the gross horse-power, with the engine running light, was 9·6. This gives an average of 23·5 horse-power for the welding. During a weld the power varied from 10·98 up to 50·7. The consumption of feed water and calculations of heat generated agree with the indicator diagrams. The time for a weld may be given in seconds as follows:—Fixing and heating, 26; taking out, 11; work on anvil, 15; refixing and reheating, 21; up to completion, 42; interval, 20; total, 135 seconds. As a comparison, 44 hand-welds were made in three hours with the consumption of $1\frac{1}{2}$ cwt. of breeze.

The welded bars were all tested at Mr. Kirkcaldy's works. The strength of the metal in the solid is 52,646 lbs. per square inch of original sectional area; in the case of electric welds broken at the welds it was 48,125 lbs., or 91·9 per cent., and in the case of hand-welds broken at the welds it was 46,899 lbs., or 89·3 per cent. Bending tests showed that electric welds cracked or broke at an average of 66°

from the straight when bent cold, and 144° when bent hot. Similar tests for hand-welds gave 138° and 147° . Full particulars of all these tests are given in tabular form.

Channel and tee iron were successfully welded, also tubes and tool steel. Welded wire rope, when cut open, shows that a very short length has been turned into a solid bar. Every variety of steel, cast, wrought, malleable, and case-hardened iron and ferro-aluminium are weldable. Iron has also been welded to steel, brass, copper, bronze, and german-silver. A list of other weldable metals is also given. In some cases the junction is probably made by fusing together rather than by true welding. The application of the process to heating rivets and to other purposes is also pointed out.

Mr. C. J. H. Woodbury* also describes the two systems of electric welding. The weld begins at the centre and proceeds radially to the surface of the pieces. There is no unnecessary waste of fuel, the heating being local, and not extending far from the weld. No manipulation is required during the process except to reduce the burr at the weld, and the heat is entirely under control. The time for making a weld varies from a fraction of a second up to two minutes, according to the size of the piece to be operated on. Nothing over two inches in diameter has yet been welded, but larger machines are in process of construction. It is not necessary to provide motive-power fully equal to the maximum demand, as the time is so short that the momentum of a fly-wheel will give the surplus energy required.

The power is inversely proportional to the time, and appears to be approximately proportional to the 2.3 power of the diameter in inches, with a slight variation in favour of quick work caused by the differences in loss of heat. The process is far cheaper than hand-welding. Up to the present it has been confined to butt-welding, but it can be used for many other purposes, such as to replace the use of rivets, screws, &c., in ornamental metal-work. In the discussion on this paper, Mr. R. W. Pope quoted a communication from Mr. A. M. Dolbear to show that electrically welded bars were stronger than those welded by hand. The application to long screws was pointed out by Mr. J. Wheelock.

Mr. Woodbury showed that the burr at the weld is considered an advantage in chains, as it prevents kinking. Pieces may be welded

* Paper read before the American Society of Mechanical Engineers; *Iron and Steel Trades Journal*, vol. xlvi. pp. 50, 85, 86.

with an almost imperceptible burr, if the proper convexity is given to the ends of the bars.

A report on electric welding has recently been made by a board of naval officers appointed by the Secretary of the United States Navy. It was found possible to weld rods up to $2\frac{1}{2}$ inches in diameter, and pipes of larger size; also dissimilar metals, different forms of cross-sections, wire cables, and rings of large or small diameter. None of the present machines are adapted for general use, but it would be possible to design one with adjustable clamps. When tested by rupture, the break did not take place at the weld, but at a short distance from it, where the metal was affected by the heat as in an ordinary weld. By the use of this process it is expected that the present accumulation of almost worthless boiler tubes could be rendered fit for service, and the quantity of spare tubes and stores on board might then be reduced. It is believed that the Thomson welding process will be found of great utility to the naval service, both on shore and afloat, for the following reasons:—It can be used (a) for welding breaks in rods without altering them either in length or shape; (b) for welding tubes; (c) for welding angles and shapes of intricate form; (d) for welding, copper, brass, cast iron, or other metals; (e) for heating metals for forging, tempering, and upsetting; and (f) for welding wire cables.*

Welding and Corrugating Cylinders.—A welding machine for this purpose is described in the *Iron Age*,† a number of illustrations being given to show the method of its application. The machine is composed of two vertically arranged parallel arms, which are supported at their lower ends, and carry at their upper or free ends welding-rolls adapted to receive the overlapping edges of the blank being formed, and to weld them together, the edges being suitably heated.

Spirally Welded Tubes.—According to Mr. W. S. Mallory,‡ the metal used at East Orange, New Jersey, for the manufacture of spirally welded tubes is a mild Bessemer ingot iron with the following composition:—

C.	Si.	S.	Mn.	P.
0·07	0·003	0·048	0·318	0·120

The material has an average elastic limit of 43,000 lbs. and an

* *Iron Age*, vol. xlv. p. 427.

† Vol. xlv. p. 756, six illustrations.

‡ *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 267–272.

ultimate strength of 63,000 lbs. The strips of metal average 20 feet long by 12 to 18 inches wide. The longest piece of piping made up to the present is 57 feet long by 10 inches in diameter. The pipes are made with flange or with spigot joints. As the spiral tends to unwind under pressure, the seams become tighter if the welds happen to be defective, which, however, they seldom are. The spiral lap of the metal acts also as a strengthening ring, so that the pipes can be made excessively light and strong at the same time. A series of tests are given below, the last column showing the ultimate strength of seamless drawn steel tubes of the same diameter and weight.

Diameter.	Weight per Foot.	Safe under Pressure.	Ultimate Strength.
Inches.	Lbs.	Lbs.	Lbs.
6	6.22	866	1408
12	15.41	727	1181
16	26.19	670	1088
20	32.25	536	871
24	38.78	446	726

Their principal uses hitherto have been for natural gas lines, conduits for compressed air, pump columns and discharge pipes in mine drainage, steam, blast and gas conduits in metallurgical works, and water mains. Their average weight is one-fifth that of wrought iron and one-tenth that of cast iron. They are made in diameters ranging from 6 to 24 inches, and machines are being designed to make 48-inch pipes from $\frac{1}{4}$ -inch metal.*

Rolling Tubes.—Mr. J. G. Gordon† describes the Mannesmann process of making seamless tubes, and quotes the explanation given by Mr. F. Siemens. To prove that the mandril takes no part in forming the tubes, some bars with reduced ends were put through the mill, and it was found that a tubular cavity was formed. The gases inside this contained 99 per cent. of hydrogen, according to Professor Finke. The power required for the production of the tube varies from 2000 to 10,000 horse-power, according to the size of the tubes. A 1200 horse-power engine is employed, and work is stored in a heavy fly-wheel to be utilised during the thirty to forty-five seconds required to convert a bar 10 or 12 feet long and 4 inches in diameter into a tube. The fly-

* For description of manufacture see *Journal of the Iron and Steel Institute*, 1888, No. I., pp. 346-348.

† *Journal of the Society of Arts*, vol. xxxviii, pp. 647-656.

wheel consists of steel plates bolted to a cast iron hub, and about 70 tons of steel wire is wound on its periphery. It is 20 feet in diameter, and revolves 240 times per minute. For heating the blanks, a Siemens regenerative furnace with an area of 789 square feet is used. The ends of the tubes are cut by machines to form American tapered thread-screws. A series of tests are given to show the superiority of these tubes over lap-welded ones. In these tubes the fibre of the metal runs spirally round the tube, while in ordinary drawn tubes the fibre is more or less longitudinal; besides which, drawn tubes have to be frequently annealed during manufacture. Further, the metal will not properly pass through the rolls unless it is of good character and free from flaws. A table is given to show the comparative weight per foot and per mile of these and of cast iron tubes. The author exhibited a tube made by this process 70 feet long, 3 inches internal diameter, and about $\frac{1}{4}$ of an inch thick. The application of this process to the manufacture of hollow railway and other axles, gun-barrels, tubes, and shells was mentioned. At present there are five works making, or about to make, tubes by this process, namely, at Remscheid, in Rhenish Prussia; at Bous, near Saarbrücken; at Komatau; at Duisburg; and at Landore.

The Laureau Pit-Heating Furnace.—Mr. L. G. Laureau* has recently designed a new form of this type of furnace. The furnace is divided into two compartments, running lengthwise and divided by hollow walls. The flame, instead of crossing a short distance, as in the ordinary form of furnace, sweeps the entire length, giving it ample time to give up its heat before escaping. The top of the furnace is covered with plates, with an air-space between them and the bricks. The rolling doors are made in two parts for ease in handling. Ordinary flange rails are bolted to the top-plates. They serve as tracks for the door-rollers and keep the top of the furnace in shape. The body of the furnace is thoroughly bound between the doors. There is a slag-pit on one side, permitting the easy removal of the small amount of cinder formed. There are eight holes, each 2 feet 4 inches by 3 feet 6 inches, capable of taking two ingots up to 16 inches square. It is better, however, to put only one ingot into each of the four end-holes, making the total charge twelve ingots. Running full and steadily, the capacity of the furnace is three rounds per hour, or thirty-six ingots. This form of furnace can be built very cheaply. Pit-heating furnaces

* *Iron Age*, vol. xlv. p. 673, four illustrations.

are intended primarily to serve for equalising heat in ingots just drawn from the pit, but this form has been used with success during a prolonged period for heating cold ingots. The first furnace of the kind described has been in continuous use for over two years at the Waugh Steelworks, Belleville, Illinois.

Three-Cylinder Boring Machine.—A machine of this kind has been designed by a Cincinnati company for boring the three cylinders of the Triumph compound engine. It has a capacity and range suitable for seven sizes, varying in diameter from 4-inch high-pressure and 8-inch low-pressure to 10-inch high-pressure and 20-inch low-pressure. The bars are adjustable between centres from 10 to 22 inches, spacing blocks being provided for keeping standard distances.

A cutter-head, containing places for three roughing tools, three finishing tools, chamfering and one counterboring tool, for boring low-pressure cylinders, is carried by each boring bar. The high-pressure cylinders are bored by double end-cutters inserted in the bars direct. Each bar is bolted to a spindle, which is driven by worm-gearing, giving a very smooth and even motion to the bar. The cylinders are secured to suitable saddle-blocks bolted to the carriage. The feed is by a screw and open and close nut in carriage. The feed arrangement is driven through worm gearing and change wheels, which give roughing and finishing feeds; these are respectively $\frac{1}{16}$ inch and $\frac{3}{16}$ inch per revolution of boring bar.

The following are some of the principal dimensions of the machine:—Bed, 40 inches wide by 14 feet long. Worm wheel, 13 inches in diameter, 2-inch pitch, and double cut. The driving cone has seven grades for a 4-inch belt, the largest diameter being 30 inches, the cone being so proportioned as to give a uniform speed for different sizes. The feed screw is 3 inches in diameter. The carriage is 4 feet wide by 5 feet long; it has also a rack, pinion, and ratchet for movement. The total weight of the machine is about 20,000 lbs.*

Radial Drilling Machine.—A balanced spindle 6-foot radial drilling machine is illustrated in the *Iron Age*.† The height of the column is 9 feet 1 inch, and the arm has a vertical adjustment of 3 feet 4 inches; this arm can be turned to any degree, swivelling on a graduated shoe.

* *Iron Age*, vol. xlv. p. 294, three illustrations.

† Vol. xlv. p. 163, two illustrations.

Plate-Bending Machine.—The *Iron Age* * publishes as a supplement two sheets of engravings of the heavy bending rolls for the naval dockyard at Mare Island. The two centre rolls weigh 35 tons each, the two side rolls weigh 25 tons each, and each of the roll housings weighs 15 tons, the whole machine weighing 250 tons. It will bend armour-plate 2 inches in thickness and 22 feet in length.

Lever Punching Machine.—A lever punching machine for punching holes $1\frac{1}{2}$ inch in diameter in plates $1\frac{1}{2}$ inch thick is illustrated in *Industries*.† The gap of the machine is 42 inches deep. A shearing slide with blades 3 feet long is attached, and also cranes for manipulating plates up to 2 tons weight.

Squaring Shears.—The *Iron Age* ‡ gives an illustrated description of large squaring shears, described as being the most recent design of the standard trimming and squaring shears. The machine will cut up to $\frac{3}{8}$ -inch plate, the length of the cut being 10 feet 4 inches. The total weight of the machine is 30,000 lbs.

Universal Milling Machine.—The *Iron Age* § publishes a number of illustrations descriptive of the arrangement and mode of working of a new universal milling machine. The illustrations include a general view of the machine, and others showing the compensating wedge, the high-speed attachment, the rack-cutting attachment, the milling-gear stud-bracket, milling off flat sides, and the spiral head. The illustrations are accompanied by a description of the machine.

Spiral-Geared Planing Machine.—The spiral-geared planing machine of Messrs. William Sellers & Co. of Philadelphia, exhibited at the Paris Exhibition, is described in full detail in the *Iron Age*, || the description being illustrated by a sheet of drawings. The reciprocating motion of the machine is produced by friction clutches instead of by shifting belts. The feed is distinct from the motion of the table, and is positively driven from a slow-running pulley through an appliance for transmitting and arresting motion. The machine is driven from either side by levers which control the table motion, and which at the same time can, at will, cut loose and arrest the feed, so that the table can be run past the stops as often as is required for the examination or adjustment of the work.

* Vol. xlv. p. 420.

† Vol. viii. p. 84, illustration.

‡ Vol. xlv. p. 254.

§ Vol. xlv. p. 992.

|| Vol. xlv. p. 912, twenty illustrations.

Seventy-two-Inch Planing Machine.—A machine to plane 72 inches wide and 72 inches high is illustrated in the *Iron Age*.* The driving-shaft is in line with the bed, and power is transmitted through noiseless tangent gearing running in oil. The velocities of the belts and the table are as 80 is to 1. The feeds are all positive and automatic. The counter-shaft pulleys are 22 inches in diameter by 6 inches face. The speed of the counter-shaft is 250 revolutions per minute.

A New Roll-Lathe.—A roll-lathe of new design, built by the Lloyd-Booth Company, of Youngstown, Ohio, is illustrated in the *Iron Age*.† The bed can be made of any length between 14 and 22 feet. The lathe is fitted with two sets of housings, the small ones to take rolls from 6 to 14 inches in diameter, and the larger ones to take rolls from 12 to 30 inches in diameter.

Riveting Plant.—A 200-ton riveting plant is illustrated in the *Engineer*.‡ It is designed for shipbuilding, engine, and boiler works, and is adapted to close steel rivets, three inches in diameter, at the rate of eight per minute in plates up to 2 inches thick. The frame has a gap of 12 feet, and is built of riveted open-hearth steel plate, 1½ inch thick, with stiffening plates and angles. The hob is of cast-steel, and weighs 13 tons, with a web varying from 4 to 8 inches in thickness. The two bolts that unite the parts are 8 inches in diameter, with buttress threads and nuts 9 inches deep. Each bolt weighs 33 cwt. The total weight is thus reduced to 35 tons from the 66 tons it would have weighed if made of cast iron. The gantries, pumps, and accumulator are also described.

Machine Tools.—Mr. R. H. Tweddell§ describes the greatly extended adoption of the system of hydraulic machines and appliances since 1877, and gives figures showing the continually increasing power and size of this class of machines. He discusses the relative value of hydraulic, electric, and pneumatic transmission of power, considered in their special relation to machine tools and appliances for transferring the work. The conditions affecting the designing of a large plant are pointed out, and the subject of the merits of the three motive powers are considered under several heads, namely, the convenient storage of power, economy, and facility of distributing the same over large areas, simplicity in its application to machine tools, and adap-

* Vol. xliv. p. 554.

† Vol. xlv. p. 911.

‡ Vol. lxix. pp. 126-127, and 134.

§ Paper read before the Society of Engineers, March 3, 1890.

tability to perform either light or heavy work. Electricity and pneumatic pressure do not fulfil all these conditions so well as hydraulic transmission. The author then refers to the various improvements in hydraulic machine tools for riveting, flanging, drilling, &c., and describes the riveting up of the plates for large bridges *in situ*. Other labour-saving appliances are also described.

Machine for Pushing Ingots from Moulds.—Mr. S. T. Wellman* has designed a hydraulic machine for pushing ingots from moulds, in which, by employing a ram having large and small telescopic plungers, the pressure may be varied according to the nature of the work required to be performed.

The Kennedy-Aiken Hydraulic Crane.—Two hydraulic cranes have been erected from the designs of Messrs. J. Kennedy and H. Aiken at the Homestead Steelworks, Pennsylvania, for the purpose of handling the slabs in the heating department of the plate-mill. They are placed in the centre of a circle formed by six heating furnaces, arranged with their working doors on the inner side of the circle. Past these runs the rail-track, and the driven roller-table of the plate train is within the range of the hydraulic cranes. These cranes, which are described in detail,† were designed to handle ingots weighing from 4000 to 5000 lbs., but the ingots handled have since reached the weight of 12,000 lbs., about 6000 tons of ingots being manipulated during the month.

Steel Wire and Wire Rope.—Professor J. von Ehrenwerth‡ publishes a German translation of a Swedish paper by R. & V. Pallin§ relating to the manufacture of hard steel wire and the utilisation of this material for rope construction purposes. The authors visited a number of works both in the United Kingdom and elsewhere. Swedish ingot metal they found to be looked upon, for this purpose, with disfavour. Still it has within recent years been employed to some extent, especially in the United States, whilst it is used largely in Sweden itself. The chemical composition of the metal is of the utmost importance. The percentage of manganese must be very high, as the wire will then harden more readily and permit of a greater tempering, the main point being that if the grain of the wire becomes somewhat

* *Iron Age*, vol. xlv. p. 256.

† *Ibid.*, vol. xlv. p. 755, five illustrations.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 1-5.

§ *Jernkontorets Annaler*, vol. xliii. Part II.

cystalline on heating, the original fine grain may be restored if manganese is present in a sufficient quantity. The author discusses the method of preparation and drawing of the wire, and in particular the mechanical means which have been adopted in various places. The methods of hardening, galvanising, and rope manufacture are also discussed. In conclusion, the author draws particular attention to the methods employed in the United Kingdom.

Rail Sections.—According to M. Clerc,* the Western Railway Company of France are replacing steel rails of 78·2 lbs. per yard by rails weighing 98·7 lbs. per yard. The lighter rails were of double-headed section, and the only modification adopted is to increase the depth of the head. The old pattern fish-plates can accordingly be used, and it is supposed that the new rails can be worn down to the same level as the old ones when they were condemned.

At the International Railway Congress held at Paris last year, the following requirements for the metal of steel rails were given, with a note that the test bars are not of the same length in all cases: †—

	Tensile Strength, Tons per Square Inch.	Extension per Cent. at Rupture.
France, Compagnie du Nord . .	44·44-47·62	13
„ Compagnie d'Orléans . .	47·62-50·79	11
„ Compagnie de l'Est . .	34·92-38·09	20
„ Compagnie de l'Ouest . .	44·44-47·62	13
„ Compagnie P.-L.-M. . .	44·44-47·62	13
„ Compagnie du Midi . .	50·79-53·97	8
„ State railways . .	47·62-50·79	11
Spain, Northern . .	38·09-41·27	18-22
Belgium, State . .	38·09-44·44	10-15
„ Grand Central . .	38·09-44·44	10-15
Austria, North-West . .	34·92-38·09	21
„ North Emp. Ferdinand . .	31·75	21
„ Austro-Hungarian State . .	31·75	21
„ Hungarian State railways . .	29·84-38·09	16-23
Sweden, State railways . .	34·92-38·09	15-20
Holland, State railways . .	33·01-41·27	15-20
Switzerland, West Simplon . .	38·09-41·27	18
„ Gothard . .	38·09	18
„ Jura-Berne-Lucerne . .	34·92	18
England, London, Chatham, and Dover . .	38·09-41·27	15-20
„ Great Western . .	38·09-41·27	15-20
„ Midland . .	38·09-41·27	15-20
„ South-Eastern . .	38·09-41·27	15-20
„ North-Eastern . .	31·75-34·92	18-22
„ London and North-Western . .	31·75-38·09	17-20
Prussia, State railways . .	31·75	17-20

* *Revue Général des Chemins de Fer*, 1890, pp. 19-22.

† *Le Génie Civil*, vol. xvi. pp. 437-439.

Observations on the wear of rails in Belgium showed that the rail decreased in height one millimetre by the passage of 33,000 trains, but the second and third millimetres required 54,000 and 100,000 trains respectively. From this it would appear that the surface or skin wears most easily, but probably this is explained by the lateral flow of the metal. Details are also given of the tonnage to produce wear in various countries, and the effect of the wear on ascending or descending gradients. The wear on the latter is of course more severe, owing to the action of the brakes; for example, when the inclination is one in fifty or greater, a wear of one millimetre is produced by the passage of 11 and of 2·27 million tons on the ascending and descending grades respectively. Besides this, the wear undoubtedly is influenced by the form of the rail.

According to Mr. P. H. Dudley,* deep-headed rails wear more rapidly than those with shallow heads, and also they flake out in thin irregular patches to the depth of one-hundredth of an inch or more. This seems to be due to the coarser crystallisation of the deep heads. Examination of the permanent way showed definite forms of permanent set, which could be traced to want of care in the track, and in some cases to want of care in the manufacture. Rails with the first form of deformation are low at the joints, with the second form they are low at the joints and the centre, and in the third form the rail is thrown into a series of short waves. Combinations of the third form with the others are frequent. The receiving end of a low joint is subjected to blows by each wheel, and soon gets cut. The second form of set is produced when the rails break joint, and the first when they do not. Corrugations or waves arise when the rails are not sufficiently stiff, or when the ballast is insufficiently cared for. A series of tests of an 80 lb. rail, designed by the author, is given; the rail was placed on supports 30 inches apart:—

Load Applied in Lbs.	Deflection in Inches.	Set.
4,000	0·0022	...
10,000	0·0091	0·0019
20,000	0·0239	...
30,000	0·0300	0·0028
40,000	0·0400	0·0036
90,000	0·1326	0·0447
120,000	0·6440	0·5143

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

The difficulties that will be experienced in substituting heavier, stiffer, and broader headed rails for lighter sections will be the want of experience of mills in finishing these heavy sections, and the wearing or shearing off the edges of the broader rails by wheels having hollow treads worn by narrower headed rails. Both these difficulties would soon disappear. At present, as a rule, too much camber is given to heavy sections when hot, and short waves are put in for each long bend that is straightened. The head of the rail might have a concave curve of an inch versed sine.

The abrasion of wheels and sleepers is much less with heavier sections. Another unexpected result is that oxidation is less, as the scale is not so readily detached on account of the stiffness of the rail. To prevent the canting over of the head, a large fillet should be used; as much as a five-eighth inch radius may be used with advantage.

In a postscript to this paper Mr. Dudley* gives some results of tests communicated to him by Mr. F. A. Delano. The following table shows several averages of these tests, made on rails resting on supports 30 inches apart:—

Load Applied in Lbs.	M'Clure Section.		Delano Section.	
	Deflection.	Set.	Deflection.	Set.
10,000	0·0091	0·0003	0·0095	0·0005
20,000	0·0189	...	0·0195	...
30,000	0·0283	...	0·0289	...
40,000	0·0372	0·0006	0·0379	0·0009
90,000	0·0847	0·0046	0·0855	0·0038
100,000	0·0962	0·0072	0·0975	0·0065
120,000	0·1399	0·0319	0·1350	0·0250

In both these sections the approximate elastic limit of the metal is 111,000 lbs. per square inch.

	Hardness.	Height of Section.	Weight per Yard.	Carbon.	Phosphorus.
M'Clure	22·91	5·18	Lbs. 83·73	Per cent. 0·425	Per cent. 0·0955
Delano	24·03	5·01	83·49	0·487	0·1023

* *Transactions of the American Institute of Mining Engineers*, vol. xviii. (advance proof).

The vertical moments of inertia were 28·61 for the former section and 27·34 for the latter.

Metal Sleepers.—The cost of maintenance of trial lengths of line laid with metal sleepers on the Netherlands State railways is given in the *Bulletin* of the International Railway Congress.* Mr. E. E. R. Tratman† gives a preliminary report on the use of metal track on railways as a substitute for wooden sleepers, in which he deals with the use of ties in the various countries of Europe, Asia, Africa, Australia, South America, and Mexico. He also describes the Post, International, Hartford, Standard, and other sleepers.

Crane for Loading Rails.—*Engineering* ‡ illustrates a crane used for loading rails on to trucks, &c., as used by the Paris and Orleans Railway. The work is done by two cranes operating together, each crane consists of a C framework, on the upper limb of which a travelling winch is carried. With this apparatus three hundred 36-foot rails are loaded daily by six men, the same work by hand necessitating twelve men.

Steel Waggon Frames.—Mr. P. F. Nursey§ describes the manufacture of Fox's solid pressed steel car frames at the Leeds Forge Works. The steel is made in three 15-ton open-hearth furnaces, and is rolled into plates which are taken to the pressing department. This building covers 124,800 square feet, and contains the hydraulic presses, which submit the heated plates to a pressure of 850 lbs. per square inch. The plate is pressed over its whole surface between dies, which simultaneously form the inward or outward flanges as required. The steel contains 0·10 per cent. of carbon, and has a tensile strength of 24 to 26 tons per square inch with an elongation of 25 to 30 per cent. in 10 inches. The bending and temper tests are those prescribed by the Admiralty, the Board of Trade, and Lloyd's. Ordinary frames weigh 4 tons 14 cwt., and these pressed frames weigh only 3 tons 14 cwt. Other advantages are the value of the worn-out frame, the interchangeability of parts, and longer life on account of their elasticity.

* 1889, p. 1138.

† *Transactions of the American Society of Civil Engineers*, vol. xxii. pp. 195-203, plates.

‡ Vol. xlviii. pp. 736 and 738.

§ Paper read before the Society of Engineers. A paper on the same subject was read at February meeting of Western Railway Club by Mr. E. M. Hughes.

The decrease in the number of parts is also an important feature, there being only fourteen parts in one of these frames as against forty-seven in ordinary frames.

Apparatus for Making Waggon Axles.—An apparatus for this purpose is described by the aid of six illustrations in the *Iron Age*.* The method consists in placing in a mould a blank of suitable length, and of a diameter approximately equal to the smallest diameter of the axle to be produced. Pressure is applied at the ends, and the blank is reduced in length, and some portions of it enlarged so as to produce the finished axle.

Ingot Iron for Bridges.—C. Stöckl† discusses the use that has been made of ingot iron in Austria for bridge construction purposes. Ingot steel has been used in one or two instances with unsatisfactory results, and this led to a Government investigation, made with a view to compare the relative suitability of weld iron, and ingot steel for girders. The results were greatly in favour of the weld iron, and this led to the erection of weld iron bridges in the construction of the Arlberg Railway. For a long time the discussion as to bridge material was considered closed, but the advances made in the metallurgy of steel within recent years have again brought the matter prominently forward. This more especially resulted from the introduction of the basic Bessemer process at the Tepnitz and Kladno works, followed by the production of the softer varieties of basic iron. It is the basic open-hearth process, however, which has had the more important results, mainly in consequence of the greater regularity in the character of the metal produced. Open-hearth metal is now being used on all the Austrian State railways for bridge purposes. The metal made at the Kladno works for the Moldau viaduct, when submitted to tensile tests, must show results within the following limits:—

Material.	Elastic Limit.	Maximum Stress.	Breaking Load.	Elongation.	Contraction.
	Tons per square inch.	Tons per square inch.	Tons per square inch.	Per cent.	Per cent.
Open-hearth metal	19.0-13.3	28.6-21.6	52.1-35.6	32-15	72-40

The chemical composition should be as follows:—

Carbon.	Phosphorus.	Manganese.	Sulphur.
0.62-0.85	0.016-0.034	0.152-0.210	0.015-0.030

* Vol. xlv. p. 212.

† *Stahl und Eisen*, vol. x. p. 20.

Ingot Iron from the Kiev Bridge.—Professor Belebubsky * has examined a link from the chain suspension bridge over the Dnieper at Kiev. It had been in use for forty years, and comparative tensile tests made with a similar link that had been stored showed the quality to be almost identical—the continuous tension for forty years had produced no change. The chemical composition of the metal is not given.

German Basic Bessemer Iron.—According to Mehrrens,† in the year 1888 in Germany, out of a total production of 4,229,484 tons of coke pig iron, 1,253,308 tons were employed in the basic Bessemer process, and only 395,878 tons in the acid Bessemer process. Very mild ingot iron is not adapted for structural purposes. The German basic metal can, however, be obtained of suitable quality from a number of works (Phoenix, Hörde, Ilsede, Aachener Hütte). Basic pig iron has the following composition :—

	Moselle.	Ilsede.	Peine.	Hörde.	Kladno.
Carbon . . .	3·00–3·50	3·22	3·38	3·00–3·50	3·50
Phosphorus . . .	2·00–2·25	2·92	2·72	under 3·00	2·40–2·60
Manganese . . .	1·50–2·00	2·38	2·00–2·50	2·00–2·50	0·40
Silicon . . .	0·35–0·40	0·11	0·18	under 0·5	0·10–0·20
Sulphur . . .	?	0·05	0·06	under 0·1	0·02–0·05

Basic Bessemer metal from the Kladno works is largely used in bridge construction, notably for the great Elbe bridge at Melnik. In Germany, however, the only bridge of basic metal is the swing-bridge in Hamburg. The Austrian Government has decided to employ exclusively open-hearth steel for bridge construction, as it has been found superior to basic metal.

Steel for Boilers.—P. Kreuzpointer ‡ observes that there is a growing disposition to dispense with iron and to use steel for the manufacture of steam-boilers, and he discusses in detail the suitability of steel for this purpose. The difficulties at first met with, due to a great extent to inexperience, led to the manufacture of a very soft variety of metal for boiler purposes, but this was accompanied by a diminution in the wearing capacity. The author arrives at the following conclusions :—

1. That steel is an entirely safe and trustworthy material for steam-

* *Stahl und Eisen*, vol. ix. p. 917.

† *Glaser's Annalen*, 1890, No. 305.

‡ *Iron Age*, vol. xlv. pp. 993–996.

boilers, and is preferable to iron, because it combines equal qualities with less cost.

2. That the material for fire-boxes should be of the very best quality, whilst for the other portions of the boiler an inferior or flange grade answers the purpose.

3. That steel with less tensile strength than 56,000 lbs. per square inch and 28 per cent. elongation is not desirable for fire-box steel, nor should the strength run above 67,000 lbs. without assurance of the skill of the steel-maker.

4. That a tensile test is a sufficient guarantee of quality if such a test is supplemented by a few simple working trials.

5. That it is best to leave to the practical experience and judgment of the steel-maker the decision as to the chemical composition of the steel.

6. Finally, that steel can be worked as well as iron, and, after some experience, with as little danger from injury by the boiler-maker.

Specifications for Steel for Fire-Boxes and Boilers.—Messrs. Carnegie, Phipps, & Co. publish the following abstracts of leading specifications for boiler steel: *—

United States Navy.—Shell: Tensile strength, 58,000 to 67,000 lbs.; elongation, 22 per cent. in 8-inch transverse section, 25 per cent. in 8-inch longitudinal section. Flange: Tensile strength, 50,000 to 58,000 lbs.; elongation, 26 per cent. in 8 inches. Chemical requirements: Phosphorus, not over 0.035 per cent.; sulphur, not over 0.040 per cent. Cold-bending test: Specimen to stand being bent flat on itself. Quenching test: Steel heated to cherry-red, plunged in water at 82° F., and to be bent round curve $1\frac{1}{2}$ times the thickness of the plate.

British Admiralty.—Tensile strength, 58,240 to 67,200 lbs., elongation in 8 inches, 20 per cent.; same cold-bending and quenching tests as United States Navy.

Bureau Veritas.—Shell: Tensile strength, not less than 60,480 lbs.; elongation in 8 inches, 20 per cent.; must withstand, after heating to dull red and being plunged into water at 82° F., being bent until the opening between the ends is three times the thickness of plate.

United States Marine.—Tensile strength, not less than 60,000 lbs.; reduction of area, 50 per cent.

American Boiler-Makers' Association.—Tensile strength, 55,000 to 65,000 lbs.; elongation in 8 inches, 20 per cent. for plates $\frac{3}{8}$ -inch thick

* *Iron Age*, vol. xlv. p. 1024.

and under; 22 per cent. for plates $\frac{3}{8}$ -inch to $\frac{1}{2}$ -inch; 25 per cent. for plates $\frac{1}{2}$ -inch and over. Cold-bending test: For plates $\frac{1}{2}$ -inch thick and under, specimen must bend back on itself without fracture; for plates over $\frac{1}{2}$ -inch thick, the sample must withstand bending 180° round a mandrel $1\frac{1}{2}$ times the thickness of the plate. Chemical requirements: Phosphorus, not over 0.040 per cent.; sulphur, not over 0.030 per cent.

Tests are to be made at the mill, three bending and three tensile tests on each heat. The failure of two tests condemns the entire heat. All boiler steel is to be open-hearth or crucible steel. Cast iron for those parts subject to tensile strains should not be permitted, and only a soft, grey, ductile metal should be used where it is permissible to have cast iron.

The Largest Krupp Gun in the World.—The American Consul at Düsseldorf, in a recent report, describes the largest gun yet manufactured at Krupp's Works at Essen. It is intended for the fortifications of Cronstadt. It is made of the finest quality of cast steel, and weighs 270,000 lbs. (about 135 tons); the calibre is $16\frac{1}{2}$ inches, and the barrel 44 feet long, the core having been removed in one piece. The greatest diameter is $6\frac{1}{2}$ feet, and the range about 12 miles. It will fire two shots per minute, each estimated to cost £300. At the trial the projectile, 4 feet long and weighing 2600 lbs., was propelled by a charge of 700 lbs. of powder, and penetrated 19 inches of armour-plate, going 1312 yards beyond the target.

Armour-Plate Trials.—Competitive trials of armour-plates were made by the Dutch Government in November 1889. The plates were made at St. Chamond, by Marrel at Rive de Gier, by Cammell and by Brown. Each measured 9 feet by 6 feet $11\frac{1}{8}$ inches, by $11\frac{1}{8}$ inches thick, and weighed about 12.4 tons. The gun was a 28-centimetre Krupp BL steel, weighing 28 tons, and the projectile was of forged steel weighing 556 lbs. The range was $262\frac{1}{2}$ feet, and the striking energy 7078.8 foot-tons per shot, with a power of perforating 14.52 inches in wrought iron. The target was strongly built, and stood well under these severe tests.

The St. Chamond plate was completely perforated by the shots and thoroughly broken up. The Marrel plate was also perforated by the shots and broken up. The first two shots were broken up and left in the Brown plate without perforating it; the third shot broke the plate in two, but showed that the union between iron and steel was

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perfect. The Cammell plate was perforated by each of the three shots, and the face was detached over a considerable area, but the plate remained in one piece. Sketches of the plates after each round are given.*

Manufacture of Galvanised Iron.—A description of three methods of galvanising iron is given by B. Preu.† The tanks in which the melted zinc is contained are made of wrought iron sheets $\frac{5}{8}$ to $\frac{3}{4}$ inch thick, and are heated only on the lower four-fifths of their height. By Winiwarter's method the tanks are nearly filled with lead covered with melted zinc to about an inch in depth. The object of the lead is to prevent the formation of hard zinc, a ferriferous alloy of zinc with up to 5 per cent. of iron. Two or three per cent. of tin is added to the zinc to promote crystallisation. The tanks have a refractory lining down to the level of the lead to prevent the corrosive action of the zinc. Plates are cleaned before dipping by a solution of zinc and ammonium chlorides in water, with a density of about 8° or 9° Baumé. The disadvantages of this method are that the zinc has to be continually renewed, and its surface constantly kept bright.

The method most generally used is to fill the bath with zinc only, protected by a layer of ammonium chloride. Zinc adheres to the plates firmly, but the fumes are objectionable. In the third process, patented by Kufler, superfluous zinc is removed from the surface of the plates by means of steel wire brushes. By this process the appearance of the plates is greatly improved, so that they are adapted for better-class goods.

Rust-Proof Process.—A plant has been installed at South Brooklyn for giving iron and steel articles a rust-proof coating by Mr. G. W. Gesner's process. It consists of a bench of two ordinary gas retorts placed side by side, and heated to a temperature of 1000° to 1200° Fahr. The articles are heated for about twenty minutes, and superheated steam is then admitted for about thirty-five minutes, after which half a pint of naphtha is permitted to flow into the retort for ten minutes. Steam is again admitted for fifteen minutes. For boiler tubes $7\frac{1}{2}$ feet long, the capacity is six tons per day. An analysis of the surface shows—carbon, 1.01; hydrogen, 0.22; sand, 6.70; and iron, 66.10 per cent.; the iron is present as oxide and in the metallic state.

* *The Engineer*, vol. lxviii. p. 438.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. p. 447.

A series of tests by Mr. B. H. Coffin * shows that the treatment has not reduced the tensile strength below the assigned limit; at the same time it has brought the elongation up to requirements. Pieces of both iron and steel were bent cold to an angle of 45° without showing any fracture or scaling of the treated surface. The following are the results of the tests:—

	Elongation.	Reduction of Area.	Elastic Limit.	Ultimate Stress.
	Per cent.	Per cent.	Lbs. per Sq. In.	Lbs. per Sq. In.
<i>Iron—</i>				
Untreated . .	{ 10·5	12·9	32,350	45,040
	{ 10·1	11·6	33,750	44,880
Treated . .	{ 8·4	13·4	33,740	42,620
	{ 6·6	11·6	33,640	45,770
<i>Steel—</i>				
Untreated . .	{ 21·6	43·3	41,960	58,250
	{ 19·1	42·8	43,050	59,120
Treated . .	{ 24·1	40·9	39,050	55,880
	{ 26·0	44·9	37,390	55,220

* *Industries*, vol. viii. p. 451, with one illustration.

PHYSICAL PROPERTIES.

Heat Dilatation of Iron from Low Temperatures.—Experiments have been made by Mr. T. Andrews* to determine the coefficients of expansion of iron and steel at low temperatures, and to discover if these factors became gradually less as the temperature fell below zero. The rolled metals consisted of round polished bars 3 inches in diameter and 13 inches long, planed perfectly square at each end; they were selected from the author's standard samples, and their chemical composition is fully given. The range of temperature chosen for the observations was from -45° C. to 300° C. For measurements at the lower temperatures the bars were placed upright in large baths of calcium chloride freezing mixture, which was surrounded by a jacket also containing freezing mixture. A large cast metal oil-bath, having a capacity of about 70 gallons of oil, was used for the highest temperature.

The bars remained immersed in the freezing-bath whilst their internal temperature was regularly ascertained by an alcohol thermometer placed in a hole in the centre of the test-bar, wherein was also placed a little alcohol. When the bars had reached and remained for some time at the registered temperature of -45° C., each was in turn removed and placed on a suitable wooden frame, and its length instantly and carefully measured by readings from a delicate micro-vernier gauge, reading to $\frac{1}{2000}$ of an inch.

The average of about thirty measurements in each case, both longitudinal and transverse, was regarded as fairly accurate. The dimensions of the bars were taken in a similar manner for the temperature -18° C. and 0° C., obtained by using freezing mixtures of snow and salt and powdered ice and snow respectively. The higher temperature observations were obtained by heating the whole of the bars in a large hot-water bath for the period necessary to ensure that the temperature throughout was uniform, and the oil-bath was used for the temperature

* *Iron*, vol. xxxv. pp. 93-94.

of 300° C. The hammered metals under observation were large forgings, 7 feet 3 inches long and 5 inches in diameter, planed perfectly square at the ends and turned and polished bright. The measurements were taken on the total length of the forgings by rigidly securing one end, and measuring the diminishing space between the other end of the forging and a fixed point situated at a distance from it. The results are recorded in the following table:—

	Co-efficients of Linear Dilatation for 1° C. between		
	—45° and 100° C.	—18° and 100° C.	100° and 300° C.
<i>Rolled Bars—</i>			
Wrought iron (Wortley best scrap)	0·0000086	0·0000114	0·0000133
Bessemer steel, soft	0·0000093	0·0000117	0·0000159
" " hard	0·0000085	0·0000101	0·0000133
Siemens-Martin steel, soft . .	0·0000088	0·0000116	0·0000144
" " hard	0·0000079	0·00001	0·0000139
Cast steel, soft	0·0000086	0·0000112	0·000015
" hard	0·0000084	0·0000101	0·000013
Cast metal, best	0·0000088	...	0·0000137
" common	0·0000088	0·000009	0·0000152
<i>Large Hammered Forgings—</i>			
Wrought iron (Wortley best scrap)	0·0000096	0·0000117	0·0000131
" " " " *	0·0000081	0·0000104	0·0000157
Bessemer steel	0·0000099	0·0000107	0·0000137
Siemens-Martin steel	0·0000093	0·0000113	0·0000142

The co-efficients of dilatation were greater in the case of the soft than in that of the hard steels, a circumstance which may be accounted for by the analyses, which show that the percentage of combined carbon was much lower in the former than in the latter, and the percentage of pure iron was consequently greater in the soft steels; this caused them to be of greater specific gravity. The results appear also to indicate that the dilatation was generally rather more in the direction of the length of the metallic cylinders than across the diameter. The result appears more marked in the large round forgings of hammered steels and wrought iron than in the case of the rolled bars. It would therefore seem probable that the crystalline particles of the metals suffer slight permanent alteration of form in the direction of their length during the process of rolling or drawing out, sufficient to very slightly affect their relative longitudinal and transverse dilatations. Furthermore, the observations of this research, conducted at these very low temperatures, experimentally confirm the suggestion of Professor Tait,

* This was a smaller forging, only 3 inches in diameter and 13 inches long.

inasmuch as the co-efficients of dilatation were found generally to decrease with the temperature below 0° C.

Magnetic Properties of Iron.—Mr. J. Hopkinson,* in his presidential address on magnetism delivered before the Institution of Electrical Engineers, deals with the magnetic properties of iron and iron alloys, and gives a summary of the work which has been done on this subject by Ewing, Tomlinson, Tait, Thompson, and others. Magnetic permeability and hysteresis or time effect are first dealt with, and also the loss of power from hysteresis. Curves are given for the magnetisation and de-magnetisation of wrought iron and steel, showing the two points at which the curves cut one another. Between magnetic and non-magnetic bodies there is a great gap, and the non-magnetisability of manganese steel proves that the magnetic properties appertain to the molecule and not to the atom. The effect of temperature is next considered, first when the temperature varies alone, and secondly when the temperature is constant and the magnetising force varies. The critical point at which magnetic properties vanish in iron is allied to its electrical resistance, its thermo-electric properties, and its recalescence. The various theories of magnetism, Poisson's, Weber's and Ampère's, are discussed, and it is shown that none of them can explain the loss of the magnetic properties of iron at high temperatures, or why iron, nickel, and cobalt should differ so greatly from all other substances.

A full discussion resulted, in which numerous fresh details were given. Mr. S. Bidwell mentioned the Villari critical points and the converse phenomena, under which iron expands with small magnetising forces, but with larger forces it contracts to less than its original length. Professor S. Thompson mentioned Chwolson's researches on temporary and sub-permanent magnetism of iron, which tend to show that iron exists in two states. He then described a small apparatus for determining the magnetic permeability of iron. Professor Ayrton described some experiments made by Dr. Wormell and also by himself, which tend to show that iron regains its magnetic properties at a white heat. Mr. Preece gave the results of experiments made at the Post Office for determining the power of retention of magnetism in various steels. The best magnetic steel of the present time contains about 3 per cent. of tungsten. In 1883, a specimen of so-called Alva steel of French production gave an induction of 5032, but this came down to 3704 in 1886. At the present time the induction scarcely reaches

* *Journal of the Institution of Electrical Engineers*, vol. xix. pp. 10-83.

2000 in the best steel obtainable. It is not only on iron that tungsten produces such an effect, for nickel alloyed with 3 per cent. of this metal has an induction of 1032, which renders it more magnetic than tool-steel of fifteen years ago. These alloys have been investigated by Messrs. J. Trowbridge and S. Sheldon.* The effect of mechanical vibration was mentioned by Mr. Evershed and Mr. Granville. Professor Barrett communicated some researches on steel containing from 1 to 21 per cent. of manganese, and gave a table showing the manganese contents, magnetic moments and breaking strains of several specimens. The results point to a chemical combination of the manganese, and support the view that there is magnetic material embedded in a non-magnetic matrix. The breaking strain, except in one instance, is low when the magnetic moment is low, and *vice versa*. The effect of temperature on the moment is less than in ordinary steel.

Magnetic Permeability of Soft Steels.—G. Henrard † has made a number of experiments at the Montefiore Institute, Liège, in order to find steels of sufficient magnetic permeability to be employed for casting field magnet cores and armatures for dynamos. Specimens of steel made at Angleur were tested, and it was found that the most permeable were very cheap, and that all could be cast and welded. Permeability does not depend on the carbon only; small percentages of other elements, particularly manganese, having a very great effect. In conclusion, the mechanical properties and analyses of various qualities of steel are discussed.

The Villari Critical Points in Iron.—The Villari critical points are the values of the force for which traction produces no change in the magnetic permeability. Mr. H. Tomlinson ‡ has investigated these points in nickel and cobalt, and has examined their variation in iron with change of load and the influence of permanent strain on them. The experiments were made by the ballistic method, using wires about 400 diameters long. In each set of observations the permeability was obtained with various loads, the magnetising force being kept the same. Diagrams are given, showing the load and percentage change of permeability, regard being paid to change of sign. It is found that

* *Proceedings of the American Academy of Arts and Sciences; Chemical News*, vol. lx. p. 312.

† *La Lumière Electrique*, vol. xxxiii. p. 593.

‡ *Proceedings of the Physical Society*, March 21, 1890.

for annealed unstrained iron the critical value of the force decreases as the load increases, and that the Villari point is much lower for temporary than for total magnetisation. Also for a given magnetising force there are generally two loads, which have no effect on the temporary magnetisation. Experiments on a permanently strained iron wire show that for magnetising forces ranging from 0.03 to 0.3 there is no critical point, and all the resulting curves are identical. There is, however, a considerable difference during loading and unloading. For greater forces the curves cease to be identical, and the maximum increase of permeability becomes less and less, till, for a certain force, the curves begin to cut the load-line. As the force increases, the point of cutting approaches the origin, and the curve begins to cut the load-line in two points. Further increase of force to 3 C. G. S. units causes the first point to disappear and the second point to recede from the origin. Finally, with sufficiently high magnetising forces the wire breaks before the second point is reached, and the curve lies wholly below the load-line.

Physical Properties of Nickel Steel.—A sample of nickel steel wire, supplied by Mr. Riley, has been examined by Mr. J. Hopkinson.* It contains about 25 per cent. of nickel and 74 per cent. of iron. When heated to over 500° C. and then cooled either rapidly or slowly, it loses its magnetic properties, which are, however, restored by cooling it to some points below 0° C. The electrical resistance depends on the condition of the metal; in the magnetisable condition it is about 0.000052, and in the non-magnetisable condition it is 0.000072 at ordinary temperatures. Curves are given showing the change of resistance as the metal is cooled or heated or changed from one state to the other. Further, the non-magnetisable metal is extremely soft, and in five specimens the tensile strength varied from 50.52 to 48.75 tons per square inch, and the extension from 33.3 to 30 per cent. The magnetisable samples were tolerably hard, and similarly varied from 88.12 to 85.76 tons, and 8.33 to 6.70 per cent. Broken fragments in each case were found to be magnetisable. As a mild steel, the non-magnetisable metal has a high breaking stress for so great an elongation. If exposed to a sharp frost, it becomes a hard steel, and remains so till it is heated to 600° C.

* *Proceedings of the Physical Society*, January 23, 1890; *Journal of the Institution of Electrical Engineers*, vol. xix. pp. 81-83.

The Electro-Resistance of Iron.—M. H. Le Chatelier* has examined the changes in the electro-resistance of iron and its alloys at high temperatures. He points out that malleable iron undergoes two reversible transformations at high temperatures, which are characterised by a greater or less absorption of heat. Osmond, the discoverer of these changes, has shown† that they play an important part in the metallurgy of iron. The first change is observed at a temperature of 730° C.—at a temperature, that is, closely approximating to the recalescence point of iron (700°). The second change, accompanied by a greater absorption of heat, takes place at 855° C.

In carbon steels Osmond has observed that the change at 855° becomes of less importance, and takes place at lower and lower temperatures as the percentage of carbon increases, until at length, for hard steels, this change becomes confounded with the point of recalescence. The author being doubtful whether this lowering of the temperature was real or only apparent, and resulting from a kind of partial hardening, brought about by the rapidity of the cooling process employed by Osmond, has re-examined the question experimentally. Osmond has observed that hardening in water has the effect of maintaining at the ordinary temperatures those varieties of iron and carbon which are stable under normal conditions above 860° and 700°. Lead-hardening, on the other hand, only maintains the variety of iron in its unstable state, without opposing the normal transformation of the iron carbide during the cooling operation. This difficulty, the author observes, can only be explained by assuming that the properties of iron vary with the temperature. Other experiments not having given satisfactory results, the author decided to examine the changes in electrical resistance which the metal undergoes when cooled down slowly from a high temperature. The experiments were made in an atmosphere of pure and dry hydrogen, but it should be pointed out that this may have had the effect of decarburising to some extent the metal under treatment. The results are shown by a series of curves. These curves show clearly the two molecular changes which take place in the case of iron and of steel, and also, the author adds, show that these changes are to a great extent independent of the proportion of foreign matter alloyed with the iron. Manganese steel containing 13 per cent of manganese, which is, however, not a steel, but a true manganese iron alloy, showed a somewhat uncertain change at a

* *Comptes Rendus de l'Académie des Sciences*, vol. cx. pp. 283-286.

† *Ibid.*, vol. ciii. pp. 743, 1135.

temperature of about 700°C . Ferro-nickel containing 25 per cent. of nickel showed a clearly marked change at 340° . Heated in dry hydrogen, it underwent no alteration, but in moist hydrogen, on the other hand, it experienced a remarkable change. Its colour passed from yellowish-grey to steel-grey; the tensile strength increased from 41 to 50 tons per square inch; the elongation fell from 65 per cent. to almost *nil*; and the elastic limit was more than doubled. The metal which had experienced this change shows a marked alteration in the conductivity at a temperature of 550° ; at higher temperatures the conductivity is identical with that of the unchanged alloy. On cooling, there is a delay in the molecular transformation similar to that which hardening induces in the case of steel; but it was impossible, even with the greatest care in cooling, to avoid this arrestation. The author believes this remarkable change in the nickel iron alloy when heated in moist hydrogen to be due to the oxidation of silicon, a small quantity of which was present in the alloy.

The iron experimented with was very pure, and contained 0.05 per cent. of carbon. The steels were of two kinds, one an open-hearth metal containing 0.6 per cent. of carbon and 0.4 of manganese, and the other a hard steel, of which the composition is not given.

The Hardness of Iron.—C. A. Casperson * determines the hardness of iron or steel by passing a current of electricity through the piece of metal under examination, and through other standard pieces. The current is ascertained which is required to produce fusion, and is compared with that necessary for the fusion of the normal pieces.

Cast Iron.—Mr. J. B. Johnson † gives the results of some experiments at the Washington University Testing Laboratory on the testing of cast iron for strength and resilience in tension, compression, and cross-breaking. The methods and appliances used are described, and a plea is made for the general adoption of resilience tests of cast iron. A rule and machine for cross-breaking tests is described, the high cross-breaking modulus of cast iron is explained, and a set of specifications is proposed.

The tensile strength should not fall below 20,000 lbs. per square inch on specimens turned down to 1 inch in diameter and 8 inches long

* *Zeitschrift des Vereines deutscher Ingenieure*, 1889, p. 955.

† *Transactions of the American Society of Civil Engineers*, vol. xxii. pp. 91-134, plates.

from castings $1\frac{1}{2}$ by 14 inches. It does not appear that the outer portions of a casting are stronger than the inner; in fact, recent tests seem to show that the interior is strongest; but this may probably be explained by the strains which originate during cooling. The resilience of cast iron is the work it does in resisting distortion, and, as cast iron usually breaks under shock, this property is of more importance than the tensile strength. Resilience is stated in inch-pounds per cubic inch, and is determined from the area of the strain diagrams. Under tensile stress the strain diagrams of cast iron are curved throughout, so the relation of stress to strain or the modulus of elasticity changes for each load. This is probably due to the initial stresses due to the cooling of the material. For measuring the extension, a pair of spirit-levels are connected to the ends of the specimen, so that the movement of the bubbles registers the stretch.

The cross-breaking strength of cast iron can only be found by a static test. In a general way the computed fibre stress at the time of rupture is about twice the tensile strength, but it may vary from $1\frac{1}{2}$ up to $2\frac{1}{2}$, depending on the toughness of the iron and on the cross-section. When the iron is tough, or when the material is concentrated near the neutral axis, the modulus is large. No mathematical explanation has proved satisfactory, the more important errors in the common theory are threefold. First, that a cross-section which is plane before bending remains so after bending; second, that the longitudinal stress varies uniformly across the section; third, that the beam is perfectly free and unstrained before bending. There does not appear any necessity for explaining the difference by shearing forces. The transverse resilience is calculated from the strain diagram in a similar way to the tensile resilience, and generally the latter is found to be about one-tenth or one-twelfth that of the former.

The objections to the use of impact machines for determining the resilience of cast iron, and of a method and machine for determining this factor by means of cross-breaking tests, have previously been discussed by the author.* The following specifications are then proposed. Castings shall be made of soft grey iron, which can readily be planed, turned, or drilled. Broken surfaces shall show a uniform dark metallic lustre, colour and close-grained texture. No blowholes, slag, &c., shall exist on the surface or in the interior. Surfaces and openings shall be smooth and full, nearly free from sand, and without any excess of metal. When struck with a hammer on a sharp corner, it shall indent

* *Journal of the Iron and Steel Institute*, 1889, No. II., pp. 421-422.

and not break. Sudden variations in thickness shall be avoided, and defective castings shall not be patched, plugged, or mended. Duplicate test-bars are to be cleanly cast when required, for tension tests $1\frac{1}{4}$ inch in diameter by 15 inches long, cross-breaking tests $\frac{3}{4}$ by 2 by 24 inches. When tested for tensile strength, it is not to be less than 25,000 lbs. per square inch, with elongation of 0.004 of its length. When tested for cross-breaking strength, half the cross-breaking load in lbs., multiplied by the deflection in inches, and divided by the weight of the bar in lbs., shall give a result of more than 30. If static strength is required, and the cross-breaking load shall be more than shown by the formula $W = 24,000 \frac{b}{h} l^2$, where W is the load in lbs. on the middle of the bar, b , h , and l are the breadth, depth, and length respectively in inches.

In the discussion Mr. G. A. Just considered that 18,000 lbs. should be the maximum for tensile strength. The results of a series of experiments made on a mixture of cast irons are then given. One-inch cubes under compression had an average ultimate strength per square inch of 121,829 lbs., and reduction in length of 13 per cent. When the test-pieces were 8 inches long the strength was reduced to 54,000 lbs. The average tensile strength was 17,081 lbs., and transverse strength of bars one inch square on supports 12 inches apart was 1825 lbs. The average shearing strength was 43,520 lbs. The tests of two lintels for spanning openings in the walls of buildings are also given with illustrations.

Behaviour of Steel under Mechanical Stress.—Mr. C. H. Carus-Wilson * gives the results of an inquiry into the properties of steel as illustrated by autographic stress-strain curves from testing machines. The permanent elongation of a bar under longitudinal stress consists of a sliding combined with an increase in volume, and the yield is caused by the limit of elastic resistance parallel to one particular direction in the bar being less than along any other direction, this direction is generally at an angle of 45° to the axis. When this lower limit is reached, sliding takes place in this direction till the consequent hardening of the bar raises the limit of elastic resistance in this direction, after which the stress must be increased to produce further deformation. From considerations based on the curves of the same material when hardened to different degrees by heating and immersion, it was concluded that the increase of elastic resistance during yield is the same for all specimens,

* Paper read before the Physical Society, December 6, 1889.

and that the yield is a measure of the hardness. The yield does not seem to take place simultaneously throughout the test-piece, but appears to travel as a strain-wave. In some specimens the load was removed before the wave had traversed the whole length. There is a close analogy between stress-strain curves and isothermal curves of gases near their liquefying points.

In seeking for an explanation of the hardening of steel under permanent strain, the author was led to believe that this is due to the displacement of the atoms within the molecules of the substance. This appears to be shown by the fact that magnetisation increases with the stress up to the yield-point, and is wholly permanent when approaching that point. These results are compared with Joule's experiments on the elongation of loaded wires produced by magnetisation, and it is inferred that there are two kinds of elongation—firstly, that produced by a relative motion of the molecules, and secondly, that due to the straining of the molecules themselves. This latter effect produces the hardening by permanent strain, and this view seems compatible with the results of Osmond's researches on the hardening of steel.

Rupture of Steel by Longitudinal Stress.—Mr. C. H. Carus-Wilson * has communicated to the Royal Society an account of experiments to determine the nature of resistance overcome during rupture of a test-bar by longitudinal stress. The true tensile strength is ascertained by dividing the load at rupture by the contracted area of the fracture. Any want of uniformity in the distribution of the stress causes the bar to break with a less load than if the distribution were uniform. Hence anything that causes a want of uniformity is prejudicial. For instance, a groove turned in a cylindrical bar will cause rupture at a lower point according as the angle of the groove is more acute. Experiment shows, however, that the plain bar is not always the strongest. So long as the want of uniformity is considerable, owing to the groove being cut with a sharp angle, the plain bar is stronger than the grooved bar; but if the groove be semicircular in section, the grooved bar is considerably stronger in spite of the non-uniformity of stress. It would seem, therefore, that a bar can be strengthened over any section by adding material above and below it, the change in section being gradual. The added material cannot increase the resistance of the ruptured section to direct tensile stress, but it can increase the resistance to shearing stress. The resistance of

* *Proceedings of the Royal Society*, March 27, 1890.

a given section of a steel bar does not then depend on its section at right angles to its axis, but at 45° to its axis, for in that direction the shearing stress is a maximum. From this it would seem that the resistance overcome at rupture is the resistance of the steel to shear. To confirm this theory, experiments were made to determine the ratio between the resistance to shear and to longitudinal tension. This ratio should be as one to two, since the greatest shearing stress is half the longitudinal stress. As a matter of fact, this was found to be so within about 3 per cent.

The appearance of the fracture of steel bars is next discussed. It appears that when the stress is uniformly disturbed in the neighbourhood of the ruptured section, the fracture is at 45° to the axis, the bar having sheared along the plane of least resistance. This tendency may be masked by a non-uniform distribution of stress.

In a further paper, Mr. Carus-Wilson* has investigated the results of the flow in strained solids. When a bar is subjected to tensile stress, the elements of the bar are distorted by the resulting shearing stresses, which attain maxima in planes at 45° to the axis. Since each inclined section in a bar is subject to the same total shearing force, the shearing strain along any section may be taken as inversely proportional to the length of the section if the bar is of uniform thickness. From these considerations the distortion of any element and of the whole bar may be ascertained. Vertical lines on the test-bar should become pinched in above and below the shoulder, whilst horizontal lines become curved in different directions according to their position. A ruled test-bar was subjected to permanent strain, and the distortion of the lines showed the characteristics predicted by the theory.

Strength of Steel in Compression.—A number of experiments have been made by Mr. J. G. Dagron† to determine the permissible load on steel under compression. Built-up columns were tested, and engravings are given of the damaged parts. The results show that the strength of steel columns is not greater than that of iron in proportion to the strength of the materials, but in proportion to their moduli of elasticity.

Testing Machines.—Illustrations are given in *Industries*‡ of a single lever testing-machine for testing the transverse strength of cast

* Paper read before the Physical Society, May 2, 1890.

† *Transactions of the American Society of Civil Engineers*, vol. xx. p. 269.

‡ Vol. viii. p. 52.

iron bars up to 8 inches long by $\frac{7}{8}$ inch in diameter, and also of a machine for testing the tensile strength of wire. In the latter machine the wire is held in automatically centering clamps, and the strain is put on by a hand-wheel and a weighted lever. A pawl holds the lever and pointer in position when the wire breaks.

Time Tests.—In autographic registering apparatus, such as the Wickstead type, a curve is traced on a revolving drum to show the behaviour of the material under test. Mr. R. H. Graham * shows that a particular rate of revolution should be given, so that the curve may properly express what has taken place. If dy be an elemental increase in length corresponding to a small interval of time dt , then the velocity of extension $\frac{dy}{dt}$ ought really to be represented by the tangent of the curve at that point. Further, there can only be one curve in which this is so. Diagrams are given of a parabolic curve obtained autographically from the extension of a spring, and the proper curve is deduced from it as a simple example, and the method of calculating the speed of rotation of the drum is given for this particular case. In order that the natural slope of the curve may properly express the velocity of extension, either a suitable rate of rotation must be given to the drum or the abscissæ must be plotted to a particular scale.

It is also a question whether the extension is a function of the time. From analogy it should be so, and in experiments with wire the curve has a greater steepness when the load is quickly added, but it is imperceptible or absent in bar and plate tests. It is also uncertain whether test-curves, traced so as to fulfil the condition for tangency, observe a fixed law during the whole time or during any particular phase of the experiment.

Colour Oxidation of the Surface of Metals.—Experiments have been made in the Physico-Technical Institution of Berlin on the surface colours produced by the oxidation of metals. The tints produced run through a regular scale, and depend on the temperature and the time during which the metals are heated. The longer the temperature acts, the firmer is the adherence of the film. It appears, however, that there is for every temperature a certain point beyond which it does not act. Sufficient air should be present to give the required amount of oxygen. Experiments with English and German tool-steel and with tungsten

* *The Engineer*, vol. lxi. p. 105.

steel show that the colours are greatly affected by the chemical composition of the metal. The degree of hardness is also an important factor, as the harder parts receive their shades later, and this gives a means of testing the homogeneity of the metal.

“Cold-Short” and “Red-Short.”—The following note has been published : *—“The words cold-short and red-short are so expressive, that their etymology would seem at first sight to be entirely free from difficulty ; but such is not the case. The earliest form of cold-short occurs in Philemon Holland’s translation of ‘Pliny’s Natural History’ (1601), where it appears as ‘colsar.’ Vernatt and Whitmore, in their patent granted in 1637 for the manufacture of iron, speak of ‘colshire’ and ‘coleshire’ iron ; whilst Dud Dudley, in his famous tract ‘Metallum Martis’ (1665), calls it ‘coldshare’ iron. A still further variation appears in the ‘Philosophical Transactions’ for 1693, in the course of a curious paper written in 1674, giving an account of the hæmatite ores of Lancashire, where the writer speaks of ‘coldshire’ and ‘redshire’ iron. Andrew Yarranton, in his ‘England’s Improvements by Land and Sea’ (1677), uses the word ‘coldshore,’ and in Moxon’s ‘Mechanick Exercises,’ published in the same year, red-short iron is described as ‘redsear.’ The earliest known instance of cold-short and red-short is in a rare folio tract of four pages, bearing the title ‘Beware of Bubbles,’ which, though undated, must from internal evidence have been issued in 1730. It forms one of a number of broadsides circulating about that time referring to a patent for the manufacture of iron taken out by Francis Wood, the well-known manufacturer of ‘Wood’s halfpence.’ The words cold-short and red-short are occupying the attention of the editor of the ‘New English Dictionary on Historical Principles,’ and any suggestions which tend to throw light on the etymology of these words will be welcomed.”

* *Engineering*, vol. xlix. p. 505.

CHEMICAL PROPERTIES.

Cuprous Sulphide in Iron.—Dr. W. Stahl * is of opinion that iron from the puddling process or the acid Bessemer process contains cuprous sulphide if the iron ore employed contained copper in combination with sulphur. The result of the following experiments made in the converter support this view. The proportion of sulphur in the iron is but slightly altered during the blow.

	S.	P.	Cu.	Si.	Mn.	C.
On leaving the cupola	0·115	0·095	0·144	1·736	2·738	3·976
After 5 minutes	0·102	0·103	0·146	1·151	2·100	3·317
After 10 minutes	0·092	0·104	0·155	0·918	2·160	2·556
After 15 minutes	0·111	0·102	0·153	0·810	1·497	1·424
After 20 minutes	0·163	0·102	0·148	0·556	0·863	0·166
After 25 minutes	0·191	0·114	0·149	0·267	0·631	0·060
On addition of spiegeleisen . .	0·196	0·115	0·161	0·274	0·836	0·186

The recent researches of Ball and Wingham † tend to show that the influence of copper on iron is in accordance with Roberts-Austen's theory that one metal has a detrimental influence on the physical properties of another only when the atomic volume of the former is greater than that of the latter. (Atomic volume of copper 7·2, that of iron 7·2.) It is therefore unnecessary, in selecting material for the Bessemer process, to avoid cupriferosus irons, provided that the iron is not in combination with sulphur.

The Alloys of Iron.—In a Report presented to the Paris International Mining and Metallurgical Congress, F. Gautier discusses the past history, the methods of manufacture, and the uses of a number of the alloys of iron used in the metallurgy of iron and steel.

Ferro-manganese.—Metallic manganese was first discovered by Gahn in 1774, and about the same date Rinmann produced a white non-

* *Berg- und Hüttenmännische Zeitung*, vol. xlix. pp. 99-100.

† *Journal of the Iron and Steel Institute*, 1889, No. I. p. 123.

strongly attracted by the magnet. The presence of cleavage faces similar to those in spiegeleisen appears also to depend on the presence of silicon. Chromium seems to increase the resistance of steel without diminishing the tenacity corresponding to its carbon contents.

An ingot of chrome steel may be forged with no more difficulty than ordinary steel of the same hardness; nevertheless, when hot, it offers greater resistance to deformation. When an ingot is cut hot, the metal is more ductile, the point of contact between the two pieces is flattened out into a thin web before breaking. It is influenced by fire even less than ordinary steel of the same hardness. In the cold, when worked in a lathe or plane, a steel containing, say, 2 per cent. of chromium is always a little softer to cut than ordinary steel; if it is properly reheated, the difference is not great. Steel that contains less chromium, even if it contains 1 per cent. of carbon, may be worked without difficulty in a lathe. Tempered in oil or water, the temper penetrates more deeply than in steel with the same percentage of carbon.

When chrome steel is melted, the chromium tends to oxidise, and form a more or less infusible slag, which clings about the crucible or casting-pot, and which permeates the metal. This slag cannot be expelled by working at any temperature, as it is not liquid like slag containing manganese. The layer of oxide formed by reheating bars, &c., is closely adherent, and is not readily dissolved by borax, so that chrome steel cannot easily be welded, especially when much chromium is present. From this it is assumed that the metal is not suitable for puddling. Again, it is difficult to produce an extra-soft steel containing much chromium, as a rich ferro-chrome must be rich in carbon if it is to be fused readily and without oxidation. If such metal could be produced, it would probably be remarkably ductile. For the above reasons chrome steel requires most delicate treatment, and it will be exceedingly difficult to use it in the manufacture of sheeting, especially for compound plates.

Rusting of Permanent Way in Tunnels.—The full results of a series of experiments by W. Thörner* on the causes of rusting of permanent way have recently been published. A large number of analyses of rust from rails and sleepers as well as drainage water, mud, &c., are given. None of the samples of rust contained iron as sulphide, but an oxidised sulphur compound was always present. This has generally been ascribed to the oxidation of pyrites in the coal burnt

* *Stahl und Eisen*, vol. lx, p. 821.

on the locomotives, but the author shows that sulphur is found in rust outside the tunnels, and accordingly he was led to look for the direct generation of sulphuric acid in the exhaust steam instead of accounting for its presence by production from sulphurous anhydride. It was found, in fact, that the exhaust steam did contain a large percentage of sulphuric acid but no sulphurous anhydride. For the preservation of the rails and sleepers it is recommended to coat them, or to protect them with limestone ballast and good drainage.

CHEMICAL ANALYSIS.

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I.—ANALYSIS OF IRON AND STEEL.

International Standards for the Analysis of Iron and Steel.

—The samples for the determination of the international standards for the analysis of iron and steel * have been prepared and forwarded by Professor J. W. Langley.† The material was prepared as nearly as possible in accordance with the directions of the British Association Committee. Ingots of crucible steel were selected from a lot of some 25 tons which came nearest to the first three standards, 1·3, 0·8, and 0·4 per cent. of carbon. It was not found possible to get the steel below 0·2 per cent. in plumbago crucibles, so a piece weighing about 100 lbs. was cut from the centre of a large forged open-hearth steel billet. The original weight of the ingots was 90 lbs., but after trimming, &c., not much over 50 lbs. could be recovered in turnings, which was rather less than the amount specified. The metal was turned in a lathe at a very slow speed and with a blunt tool. The whole time of turning was between three and four months. In regard to pulverising the drillings, Professor Langley found that a noticeable quantity of foreign material was produced in any method. Between chilled rolls the shavings only flattened. They were sifted through a 30-mesh sieve, and the fine material so obtained, which was small in quantity, was placed in a separate enclosure. The rest of the drillings are as nearly homogeneous as it is possible to make them, because they have been

* Compare *Journal of the Iron and Steel Institute*, 1889, No. I., pp. 391-393.

† *Chemical News*, vol. lx. pp. 247-248.

made from "dead melted" stock formed at one heat from a single crucible. The materials have been produced at the Crescent Steel Works of Pittsburgh.

The fifth standard, with 0·08 per cent. of carbon, from Bessemer stock, will be prepared shortly.

Tintometer.—Mr. J. W. Lovibond* describes a modification in the use of his tintometer† for the determination of colour. The new departure is founded on the fact that neutral grey, under certain known conditions, is a combination of 1 red, 1·2 yellow, and 2·4 blue in the original scales, and these proportions hold good at all depths. By assuming these values to be the units of their respective colours, a simple relationship of equality between these primaries is established, as far as the production of neutral grey is concerned. By removing any one unit a combination of the other two colours is left, and simple binary colours can be tested. Colours with three components are tested by the standard grey glasses, with additions of the required colours. Tables are given to show the variations of colour determinations under different lights, and to show that all ordinary daylight is available for work when the same light is used for both sides of the instrument. For reproduction of the scales, standards have been deposited at the colleges of Liverpool, Leeds, and Bradford.

The Determination of Carbon.—An apparatus for the determination of carbon in iron or steel, by the Wiborgh method, is described by W. Thörner.‡ The vessel for measuring the carbonic anhydride is narrowed at its lower part, as the volume is often very small, to give readings between 75 and 100 cubic centimetres. The apparatus is similar to that described by Dr. M. A. von Reis.§ Comprehensive tables are given for the calculation of the carbon from the measured amount of the carbonic anhydride at various temperatures and pressures.

The Determination of Phosphorus.—K. Borman|| has improved Götz's method of estimating phosphorus in iron, so that it can be applied to iron rich in carbon. Dissolve 1·2 grammes of the sample in

* *Journal of the Society of Chemical Industry*, vol. ix. pp. 10–15.

† *Journal of the Iron and Steel Institute*, 1888, No. II., p. 329.

‡ *Zeitschrift für angewandte Chemie*, 1889, pp. 641–650.

§ *Journal of the Iron and Steel Institute*, 1889, No. II., pp. 475–476.

|| *Zeitschrift für angewandte Chemie*, 1889, pp. 638–639.

25 cubic centimetres of nitric acid, concentrate the solution as much as possible, and add 8 to 16 drops of a potassic permanganate solution containing 12 grammes to the litre. Dissolve the precipitated peroxide of manganese in hydrochloric acid, and again concentrate. Mix the solution while hot with 10 centimetres of a 25 per cent. solution of ammonic nitrate and 25 centimetres of Finkener's ammonic molybdate solution. Transfer the solution to a pear-shaped vessel with a graduated tubular prolongation at its narrow end, and rotate in a centrifugal machine for two minutes. The molybdate precipitate collects in the tube, and can be measured. A single determination takes half an hour, but sixty to eighty can be completed in five or six hours, and the results agree closely with gravimetric methods. Silicon up to 0.25 per cent. does not affect the results, but above that percentage gelatinous silica separates.

G. Weissmann* recommends the following modification of Reis' method for the rapid and accurate determination of phosphorus in pig iron, steel, &c. Five grammes of the metal are heated with dilute nitric acid till rapid action ceases, and 30 to 40 cubic centimetres of the concentrated acid are then added. After complete solution, potassic permanganate is added till a brown precipitate appears. The solution is then treated with hydrogen peroxide, and made up to 250 cubic centimetres, of which 100 are taken, and the requisite amount, from 50 to 100 centimetres, of a standard ammonic molybdate solution added. It is then heated to 80° or 90° C. for an hour, cooled, filtered, and washed with dilute molybdate solution. The precipitate is dissolved in ammonia, and magnesia mixture added drop by drop to the solution, which should not exceed 60 centimetres in bulk. The precipitate is allowed to settle for two hours, filtered, washed with dilute ammonia, dried, and ignited. The weight in grammes multiplied by 13.975 gives the percentage of phosphorus. The process takes four to five hours, and gives accurate results. An approximate result is more speedily obtained by washing the molybdate precipitate with a 10 per cent. solution of ammonic nitrate and weighing it, after ignition at a low red-heat, as $\text{Mo}_{24}\text{O}_{68}\text{P}_2\text{O}_5$. One gramme equals 1 per cent. of phosphorus. Directions are given for the preparation of the ammonic molybdate solution and the magnesia mixture.

Dr. M. A. von Reis† has published the results of an examination of the determination of phosphorus by the aid of the Götz centrifugal

* *Chemiker Zeitung*, vol. xiii. pp. 1604-1605.

† *Stahl und Eisen*, vol. ix. p. 1025.

measuring apparatus. The modified process adopted by the author gave satisfactory results.

The Determination of Sulphur and Silicon.—In the determination of sulphur in iron by precipitation as basic sulphate, Mr. L. Archbutt* shows that the usual objections to the process are misleading or exaggerated. Even in highly dilute solutions very nearly all the basic sulphate is precipitated if sufficient excess of basic chloride is added and time enough is given. These experiments proved, however, that it is not necessary to dilute the solution, and further experiments showed that the presence of free acid is not objectionable, but rather advantageous as the solution filters more quickly. Precipitation is also practically complete in two or three hours, though it is convenient, as a general rule, to let the solution stand all night.

To determine the silicon and sulphur, 5 grammes of the metal are dissolved in a heated mixture of nitric and hydrochloric acids, a few crystals of potassium chlorate are added, and the solution is evaporated to dryness. The residue is taken up with hydrochloric acid, evaporated again, and then taken up with hydrochloric acid a second time. The solution is partly evaporated, and fresh acid is added. It is then slightly diluted and filtered. The residue is washed, burned, and weighed as silica. The dark-coloured filtrate is less than 70 cubic centimetres; 5 centimetres of a 10 per cent. solution of barium chloride is added, and the precipitated barium sulphate may be filtered off after two hours. The precipitate is easily washed clean, and the results obtained agree well with those obtained by the absorption method.

The Determination of Sulphur.—Mr. J. B. Cohen† describes Wiborgh's method of determining sulphur in iron and steel. A wide-necked flask is provided with a stopper through which passes a funnel-tube and a glass cylinder funnel, which is covered with muslin soaked in a 5 per cent. solution of cadmium acetate. The muslin is held by a rubber band. The flask is half filled with water, which is boiled to expel air. Then 0.1 to 0.8 gramme of iron is introduced, and sulphuric acid is slowly run in. Boiling is continued for five minutes after the iron is dissolved to drive off all the sulphuretted hydrogen. The percentage is determined by comparison of the shade on the muslin with standards prepared from iron of known composition; six shades are usually sufficient.

* *Journal of the Society of Chemical Industry*, vol. ix. pp. 25-27. † *Ibid.*, p. 16.

The Determination of Manganese.—L. Blum * points out the necessity, when precipitating manganese with ammonium sulphide in the presence of lime, to precipitate from a boiling solution, and to filter rapidly, as calcium hyposulphite shows a tendency to crystallise out of the solution.

The Determination of Chromium.—A. Ziegler † determines chromium in rich chrome iron (ferro-chrome) by fusing 0.5 gramme of the metal in a platinum crucible half-filled with sodium bisulphate. The crucible is covered, and the fusion is continued for two to three hours, the temperature being kept as low as possible. The fused mass is then extracted with water, the filtrate reduced in a flask with sodium hypophosphite, a slight excess of zinc oxide added, and, after settling, the whole is rapidly filtered and washed. The zinc oxide, containing the chromium, is dissolved with hydrochloric acid in the same flask as that in which the precipitation took place. The undissolved residue from the fusion is re-fused with a mixture of 3 parts of soda and 2 parts of nitre, the fused mass extracted as before, and the filtrate added to that from the previous solution. The whole is then evaporated to dryness, dissolved and filtered, precipitated twice with ammonia to separate the zinc from the chromium, the precipitate is fused with the nitre flux to separate any iron that may be present, then re-dissolved, reduced, and the chromic oxide precipitated twice with ammonia.

The Analysis of Chrome Iron.—R. Fresenius and E. Hintz ‡ state that a chrome iron having the composition :—

Chromium.	Iron.	Carbon.
61	28	9

was scarcely attacked by acids. For its analysis combustion in a current of chlorine was employed, one portion being used for the determination of the metals, and another portion of 5 grammes for the determination of the total carbon, phosphorus, and sulphur, whilst for the determination of the graphite 10 grammes of the finely-divided metal was treated with hydrochloric acid, frequently renewed during a period of several weeks.

According to A. Ziegler, § no single reagent completely attacks ferro-

* *Zeitschrift für angewandte Chemie*, 1889, p. 454.

† *Stahl und Eisen*, vol. x. p. 346.

‡ *Zeitschrift für analytische Chemie*, vol. xxix. pp. 28–35.

§ *Dingler's Polytechnisches Journal*, vol. cclxxiv. pp. 513–528.

chrome. It may be fused with a strongly oxidising fusing mixture, or it may first be exhausted with hydrochloric acid and the residue fused with fusion mixture. The residue from the aqueous extract is dissolved in hydrochloric acid, and the solutions examined together or separately. Silica is separated by evaporation to dryness with hydrochloric acid. The solution containing iron, manganese, and chromium, after separation of the silica, is treated by a slight modification of Reinhardt's process.* Chromium steel is preferably dissolved in hydrochloric acid and treated by the same process. If the Eggertz test is used for the determination of carbon, a chromium steel must be taken as a standard, as the chromium gives a grey tone to the solution. Carbon is, however, best determined by combustion.

The Analysis of Tungsten Steel.—Methods of determining the percentage of tungsten in commercial tungsten and tungsten steel are given by A. Ziegler.† Two samples of commercial tungsten for steel-making contained 75 and 91 per cent. respectively; they were in the form of a brownish or black powder. The finely-powdered tungsten or tungsten steel is fused with sodium nitrate in a silver crucible, the fused mass is extracted with water, and the filtered solution evaporated to dryness with nitric acid. The residue is re-dissolved, and tungstic acid precipitated with an acid solution of ammoniac nitrate. The precipitate is ignited and weighed as tungstic oxide. The residue from the fusion may contain tungsten, which will be evident on treatment with hydrochloric acid, as it will only dissolve slowly or will leave a yellow residue. In the latter case the residue must be re-fused, and the hydrochloric acid solution must be freed from its acid by evaporation with nitric acid, and the tungsten precipitated by mercurous nitrate in a nearly neutral solution. Iron and manganese are determined in a second portion, and silicon in a third. For silicon, the solution is evaporated with sulphuric acid, and the insoluble silica and tungstic acids are heated with hydrofluoric acid, which causes the silica to volatilise, so that it is determined by difference. Sodium bisulphate may be used as a flux instead of sodium nitrate, but with less accuracy. Ferro-tungsten by an alternative method is attacked with hydrochloric or sulphuric acid, and then the procedure is somewhat similar to that above. Carbon is determined by the Eggertz method.

* *Journal of the Iron and Steel Institute*, 1889, No. II., p. 480.

† *Dingler's Polytechnisches Journal*, vol. cclxiv. pp. 513-528.

The Determination of Aluminium.—Mr. J. E. Stead * describes a method for estimating aluminium in iron and steel. Silicon is separated in the usual manner; after which aluminium with a little iron is separated by means of saturated solutions of hyposulphite and phosphate of sodium. The reagents must be free from silica and alumina; sodium hydrate made from sodium is preferred. The process is carried out as follows:—Dissolve 11 grammes in 44 cubic centimetres of concentrated hydrochloric acid; separate the silica and bring the solution up to 200 centimetres. Add 3 centimetres of the phosphate solution, and then add ammonia till a slight permanent precipitate is formed in the cold. Boil, and add 50 centimetres of the hyposulphite; continue to boil for about an hour till all the sulphurous anhydride is removed. Filter, and wash thoroughly; then dissolve the precipitate in hydrochloric acid, leaving the sulphur on the filter-paper. Evaporate to dryness in a platinum dish, add 2 grammes of solid sodium hydrate and enough water to dissolve it. Evaporate and heat to fusion. Cool, add water, and boil, then dilute up to 110 cubic centimetres when cold, and filter through a dry filter-paper. Take the first 100 centimetres, the equivalent of 10 grammes of metal, add 3 centimetres of sodium phosphate solution after it is rendered just acid with hydrochloric acid. Boil with large excess of hyposulphite till free from sulphurous anhydride, then add 2 centimetres of sodium acetate; boil for two minutes, filter, dry, ignite, and weigh. The precipitate contains 22·36 per cent. of aluminium, and consists of AlPO_4 . The determination takes twelve hours.

II.—ANALYSIS OF IRON ORES AND SLAG.

The Volumetric Determination of Iron.—A. Parthiel † describes the following volumetric method for the determination of iron in a mixture of iron and magnetic oxide:—One gramme of the material is dissolved in 40 to 50 cubic centimetres of dilute sulphuric acid. Permanganate solution is then added till the decolorisation is complete, any excess of permanganate being destroyed by the aid of sugar. The solution is diluted to 200 cubic centimetres, and one quarter of this solution added to a strong solution of 2 grammes of potassium iodide, a few cubic centimetres of hydrochloric acid being also added.

* *Journal of the Society of Chemical Industry*, vol. viii. pp. 965-966.

† *Apotheker Zeitung*, vol. v. p. 55.

After allowing to stand in a closed vessel for an hour, the iodine which has separated out is titrated with sodium hyposulphite.

C. Reinhardt* adopts the following method for the estimation of iron by potassium permanganate in hydrochloric acid solutions. Ignite $\frac{1}{2}$ to 1 gramme of the dry sample till free from carbon and sulphur, dissolve in 25 to 30 cubic centimetres of hydrochloric acid of specific gravity 1.19. Warm, and gradually reduce with stannous chloride in slight excess. The excess of the stannous salt is removed by the addition of 60 centimetres of mercuric chloride solution, and the solution is then diluted with 1.5 litre of water, in which is 60 centimetres of a solution containing manganous sulphate, phosphoric and sulphuric acids. The solution is then titrated with permanganate till a pink colour appears. The various solutions are prepared as follows:—The standard permanganate contains 6 grammes per litre, and the mercuric chloride 50 grammes per litre; the stannous chloride contains 30 grammes of tin per litre; and the manganous sulphate solution is made by mixing 1000 cubic centimetres of phosphoric acid, 1.3 specific gravity, with 600 centimetres of water and 400 centimetres of sulphuric acid, 1.8 specific gravity. The mixture is then poured into a litre of water containing 200 grammes of manganous sulphate, the whole being made up to three litres.

The Volumetric Determination of Chromium in Chrome Iron Ore.—C. Reinhardt† fuses chrome iron ore with soda-lime and potassium chlorate, dissolves in water, adds hydrochloric acid or sulphuric acid if much manganese is present, warms and reduces with a measured quantity of ferrous sulphate solution containing 25 grammes per litre. The solution is titrated back with the permanganate and manganous sulphate recommended by the author‡ for the titration of iron.

The Determination of Phosphoric Acid in Slags.—G. Arth§ points out a probable source of error in eliminating by means of nitric acid the residual hydrochloric acid from slag from which it has been desired to remove silica. During this process a tetra-hydrated ferric phosphate is precipitated, which differs from the normal ferric phosphate in not undergoing dehydration at 110° C.

* *Chemiker Zeitung*, vol. xiii. pp. 323–325.

† *Ibid.*, vol. xiii. p. 430.

‡ See preceding abstract.

§ *Bulletin de la Société Chimique*, vol. ii. pp. 324–327.

The Precipitation of Alumina and Ferric Oxide.—G. Lunge* discusses the precipitation of these oxides by ammonia. He agrees with Blum that it is desirable to precipitate in the presence of ammonium chloride, using a slight excess of ammonia. If by a too lengthy boiling the ammonia is driven off and the ammonium chloride partially decomposed, the ferric oxide and alumina will be partly re-dissolved.

The Determination of Lime.—O. Reitmair† has modified Immen-dorf's method for the determination of lime in the presence of phosphoric acid, iron, manganese, magnesia, and alumina. Immen-dorf precipitates the lime in basic slag, silica being absent, with ammonium oxalate, and titrates with permanganate. The author shows that this lime precipitate always contains manganese, and, if allowed to stand too long, also iron. It has therefore to be re-dissolved, and precipitated as oxalate from an acetic acid solution.

The Determination of Magnesia.—L. Blum‡ points out that when determining small quantities of magnesia, the precipitate collects much more rapidly if the magnesia is precipitated by sodium phosphate instead of by sodium ammonium phosphate.

III.—FUEL ANALYSIS.

The Determination of Sulphur in Coal.—R. Brullé§ states that the sulphur in coal is not completely estimated by the usual methods, owing to its partial volatilisation. The method he adopts is to mix one gramme of the finely powdered fuel with 20 grammes of a mixture of equal parts of nitrate and carbonate of potassium. The whole is placed in a platinum trough 11·8 inches long, by 0·59 inch deep and broad. It is covered with a little more of the mixture, and the trough is closed by a platinum slide. The tube is heated slowly from one end to the other, and the contents are fused. The fused mass is then dissolved out in water, and the sulphate in the solution determined in the usual manner after the separation of the silica.

* *Zeitschrift für angewandte Chemie*, 1889, p. 634.

† *Ibid.*, pp. 357–362.

‡ *Ibid.*, p. 452.

§ *Le Génie Civil*, vol. xvi. p. 415.

IV.—*GAS ANALYSIS.*

Analysis of Producer Gas.—For the examination of producer or water-gas, W. Thörner * recommends the use of burettes surrounded by a water-jacket which is in communication with a tank containing water at the temperature of the room. The jacket should be fused on to the burettes to prevent leakage. Carbonic anhydride and hydrogen are removed in the usual manner, and the heavy hydrocarbons of the benzene and ethylene series are then absorbed by fuming sulphuric acid. For this, the pipette should have ground-glass capsules, and the upper bulb should contain fragments of glass. Carbonic oxide is best absorbed by a fresh solution of cuprous chloride in hydrochloric acid. Hydrogen is then abstracted by means of palladium asbestos. Producer gas after this treatment still contains marsh-gas, and this is removed by combustion with oxygen, which is prepared by electrolysis. The apparatus for the preparation of oxygen conveniently consists of a U-tube with two electrodes in the graduated limb and one in the other, so that either hydrogen, oxygen, or a mixture of both can readily be obtained. The apparatus for burning marsh-gas with oxygen consists of an arrangement of bulbs with thick silver wires fused in them, the ends being connected by a thin platinum spiral.

* *Zeitschrift für angewandte Chemie*, 1889, pp. 641-650; *Stahl und Eisen*, vol. x. p. 33.

Coal Output in Eastern Scotland.—Mr. R. Moore * gives diagrams showing the amount of coal raised from various depths in the Eastern District of Scotland during 1874 and 1888. The amounts were as follows :—

Depth in Feet.	1874.	1888.	Increase or Decrease.
	Tons.	Tons.	Tons.
100	878,091	359,559	— 518,532
200	2,319,653	2,336,522	+ 16,864
300	2,069,084	2,227,542	+ 158,458
400	2,065,936	1,760,883	— 305,053
500	1,151,247	2,248,901	+ 1,097,654
600	639,838	2,027,121	+ 1,387,283
700	357,652	1,136,479	+ 778,827
800	330,051	1,129,320	+ 799,269
900	370,769	1,448,754	+ 1,077,985
1000	...	825,381	+ 825,381
1100	...	284,910	+ 284,910
1200	...	30,000	+ 30,000
Totals	10,182,326	15,815,372	+ 5,633,046

II.—AUSTRALASIA.

Mineral Statistics.—The statistical register of New South Wales furnishes the following details of exports for 1889 as compared with 1888 :—

	1889.	1888.
	Tons.	Tons.
Coal	2,387,702	1,923,872
Coke	9,522	15,249
Fire-clay	12	14
Iron oxide	489	764
Manganese ores . . . . .	...	23

The production of coal in 1888 is returned at 3,203,444 tons, representing a value of £1,455,198, as compared with 2,922,497 tons, valued at £1,346,163, in the previous year. The number of persons engaged in coal-mining amounted to 9301 in 1888. During that year

* *The Colliery Guardian*, vol. lix. pp. 16 and 210.

3747 tons of pig iron were made, but not from ore produced in the colony.

According to the report on the mining industry of New Zealand, the production of coal in that colony in 1888 amounted to 613,895 tons, valued at £336,218. The production of manganese ore during the same year is estimated at 1085 tons.

According to the official Blue-Book, the production of coal in Queensland amounted to 311,412 tons, valued at £127,947.

In South Australia no coal or iron ore is produced, but the Statistical Register gives the production of manganese ore in 1888 as 51 tons, valued at £3507.

Tasmania produced 41,577 tons of coal, valued at £16,413; and Victoria produced 3573 tons of coal.

III.—AUSTRIA-HUNGARY.

The Iron Trade of Austria.—Dr. M. Caspaar* discusses the progress of the foreign iron trade of Austria-Hungary. He shows that 95 per cent. of the total imports is from Germany, the only other iron trade imports of any importance being by sea or from Italy. Only about 20 per cent. of the iron trade exports, however, goes to Germany. With regard to the trade with Russia, it is found that the manufactured articles formerly exported are now being replaced by exports of pig iron, and, on the whole, the trade is steadily diminishing. With Roumania, too, the Austrian iron trade has fallen off, but within the last three years the trade with Servia has more than doubled. Italy, also, is now taking a much larger quantity of Austrian hardware than was formerly the case, but the increase in the trade is mainly due to the larger exportation of pig iron. The exports to the various countries are shown in tabular form, the quantities and values of the main items being given for the years 1885–88.

Imports and Exports.—The following table † shows the imports and exports of the Austro-Hungarian monarchy during the year 1889 compared with 1888:—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxv. ii. pp. 110–112.

† *Austria*, 1890, Part II.

	Imports.		Exports.	
	1889.	1888.	1889.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ores	46,492	37,152	91,627	38,729
Pig iron	95,127	68,483	8,714	9,331
Manufactured iron and steel	21,922	25,476	35,074	32,473
Machinery	27,896	21,894	8,899	7,817

Petroleum in Austria.—Of the 263 petroleum works in Austria in 1888, 215 were at work. These gave employment to 3019 workpeople, and produced 64,882 tons of petroleum, an increase of 35·68 per cent. as compared with the production in 1887.

The ozokerite works numbered 82, giving employment to 5886 workpeople, and producing 8783 tons of ozokerite.*

Iron Trade Statistics of Hungary.—The official statistics relating to the mineral production of the countries subject to the Hungarian Crown, including Croatia and Slavonia, show the production of coal and pig iron during the year 1888 to have been as follows: †—

	Metric Tons.
Coal	850,691
Lignite	1,874,201
Forge pig iron	194,085
Foundry pig iron	10,021

IV.—BELGIUM.

The Belgian Iron Trade.—Great changes have taken place in Belgium in recent years in connection with the iron industry. Formerly puddled iron was made on a large scale in the Valley of the Heule; now it has passed almost completely to the valley of the Sambre. Again, the blast furnaces of the Charleroi district are passing out of existence, and the new districts of Longwy and Luxemburg are rapidly springing into importance.‡

Iron Trade Statistics.—The Belgian production of iron and steel in 1889 and 1888 was as follows:—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 72.

† *Ibid.*, p. 83.

‡ *La Semaine Industrielle*, January 16, 1890.

	1889.	1888.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Per Cent.
Foundry pig iron . . .	89,097	58,814	+ 51·48
Forge pig iron . . .	606,785	607,193	- 0·06
Bessemer pig iron . . .	152,378	160,843	- 5·27
Totals	848,260	826,850	
Rails and plates . . .	143,506	123,045	+ 16·62
Various descriptions . .	476,548	424,773	+ 12·18
Total manufactured iron	620,054	547,818	
Cast steel, ingots, &c. . .	248,641	231,847	+ 7·24
Forged steel, rails, plates, &c.	236,186	185,417	+ 27·38

The total production of coal in Belgium amounted to 19,810,118 tons in 1889, an increase of 3·07 per cent. over the production in 1888.*

Imports and Exports.—The following table† shows the Belgian iron trade imports and exports for 1889 and 1888:—

	Imports.		Exports.	
	1889.	1888.	1889.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,805,210	1,746,984	157,327	148,310
Pig iron	243,190	211,055	14,513	9,722
Scrap iron	24,608	25,267	7,559	3,609
<i>Wrought Iron—</i>				
<i>a.</i> Wire	3,149	3,232	4,841	3,751
<i>b.</i> Rails	611	574	14,629	10,444
<i>c.</i> Sheets	2,054	1,266	56,165	44,786
<i>d.</i> Other kinds . . .	11,664	8,165	257,352	250,717
<i>Manufactured Iron—</i>				
<i>a.</i> Nails	600	551	13,820	13,278
<i>b.</i> Other wrought iron manufac- tures	3,694	3,517	37,327	24,168
<i>c.</i> Castings	2,204	938	28,165	21,199
Cast steel	6,515	1,275	3,151	5,396
Steel rails	1,099	250	67,979	63,050
Steel sheets and wire	3,520	2,510	36,660	24,886
Wrought steel	1,318	886	8,395	4,012

* *Bulletin du Ministère des Travaux Publics*, vol. xxi.

† *Moniteur Belge*, February 2, 1890.

The exports and imports of coal and coke were as follows :—

	Coal.		Coke.	
	1889.	1888.	1889.	1888.
Exports . . .	Metric Tons. 4,257,694	Metric Tons. 4,141,908	Metric Tons. 1,220,325	Metric Tons. 1,060,754
Imports . . .	1,002,194	1,033,169	18,529	27,461

V.—CANADA.

Mineral Statistics.—Dr. A. R. C. Selwyn, Director of the Geological Survey of Canada, gives the following statistics for 1889 :—

	Quantity	Value.
		£
Charcoal bushels	1,426,800	16,715
Coal tons	2,719,469	1,114,148
Coke "	54,539	31,008
Fireclay "	400	960
Graphite "	220	326
Iron "	58,783	442,012
Iron ore "	84,181	30,328
Limestone for flux "	22,122	4,382
Manganese ore "	1,447	6,363
Petroleum barrels	704,690	134,596
Pig iron tons	25,921	99,972
Steel "	26,333	183,564

The quantities given are in tons of 2000 lbs. Some returns for iron have yet to be received.

Output of Coal in British Columbia.—The output of coal from the collieries of Vancouver Island amounted during 1889 to 548,503 tons. Of this total the Wellington mines furnished nearly one-half. The value of the coal at the pit's mouth was about 19s. per ton; the men employed numbered over 2300.*

Mr. W. Dick, Inspector of Mines for British Columbia, contributes to the Report of the Minister of Mines detailed information respecting the progress of the coal trade in that district, and a full description of

* *The Canadian Mining Review*, vol. ix. p. 7.

the various collieries. The work and ventilation at the different pits in the Nanaimo, Wellington, and East Wellington collieries, and at the Union Colliery, Comox, are fully dealt with. These districts have recently been described by Mr. G. M. Dawson.* In addition to these districts, a pit is being sunk on the Tumbo Island, at the south-east entrance of the Straits of Georgia, in order to reach coal at about 600 feet from the surface. Prospecting is also being carried on by boring in other situations.

Iron Ore Resources of Eastern Quebec.—In a paper on the mining industries of Eastern Quebec, Dr. R. W. Ells,† of the Geological Survey of Canada, states that iron ore deposits occur at various points, and that some of them are of great purity and excellence. The great drawback at present to their successful working is the lack of suitable fuel for smelting, wood for charcoal being too scarce in the immediate vicinity, whilst the geological formations in Quebec and Ontario are such as to render the possibility of finding coal out of the question. Should the problem of cheap transportation of coal from the collieries of Nova Scotia, or of the United States, to some central point, such as Montreal, ever be solved, it is confidently anticipated that the iron ores will form no inconsiderable factor in the mineral wealth of Eastern Quebec.

Mineral Statistics of Nova Scotia.—The Report of Mr. E. Gilpin, Inspector of Mines for Nova Scotia, gives the following statistics of production :—

	1888.	1889.
	Tons.	Tons.
Iron ore	41,611	45,907
Manganese ore	88	67
Coal	1,776,128	1,756,279
Coke	29,808	35,505
Limestone	15,448	19,000

The total sales of coal in 1889 were 1,555,107 tons, of which the United States took 29,986 tons, or about the same as in the previous year. Sixteen accidents were reported in the Pictou field, of which

* *Journal of the Iron and Steel Institute*, 1889, No. II., pp. 341-342.

† *Transactions of the American Institute of Mining Engineers*, vol. xix. (advance proof).

two were fatal. Some trouble was caused by gas. In Cape Breton there were ten accidents, including five fatal ones. One explosion of gas occurred.

VI.—FRANCE.

Iron and Steel.—The production of pig iron for 1889 is stated to have been as follows : *—

Description.	Forge Pig Iron.	Foundry Pig Iron.
	Metric Tons.	Metric Tons.
Coke pig iron . . .	1,299,167	409,161
Charcoal pig iron . .	6,281	2,080
Mixed brands . . .	1,296	4,495
Totals . . .	1,306,744	415,736
Totals in 1888 . . .	1,306,465	376,884
Increase . . .	279	38,852

The total production of pig iron thus amounted to 1,722,480 metric tons, against 1,683,349 tons in 1888, the increase being 39,131 tons.

The production of manufactured iron was as follows :—

Description.	1889.	1888.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Puddled rails	550	827	— 277
Merchant iron, puddled	526,159	539,135	...
„ „ charcoal	7,893	11,429	...
„ „ obtained by reheating . .	141,015	148,530	...
Total merchant iron	675,067	699,094	— 24,027
Plates, puddled	102,037	94,616	...
„ charcoal	2,019	2,282	...
„ by reheating	13,685	20,154	...
Total plates	117,741	117,052	+ 689
Total production	793,358	816,973	— 23,615

* *Bulletin du Comité des Forges*, No. 250, pp. 158-167.

The production of steel was as follows :—

Description.	1889.	1888.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Rails, Bessemer	138,412	163,901	...
„ open-hearth	6,935	9,157	...
Total rails	145,347	173,058	— 27,711
Merchant steel, Bessemer	134,427	117,728	...
„ „ open-hearth	127,218	111,138	...
„ „ puddled	10,083	9,690	...
„ „ cement	1,581	1,342	...
„ „ crucible	11,688	9,280	...
„ „ scrap	9,954	9,886	...
Total merchant steel	294,951	259,064	+ 35,887
Plates, Bessemer	31,947	28,383	...
„ open-hearth	48,947	53,192	...
„ miscellaneous	7,829	3,597	...
Total plates	88,723	85,172	+ 3,551
Total steel	529,021	517,294	+ 11,727

Coal.—The output of the French collieries is stated * to have been as follows :—

Description.	1889.	1888.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Coal and anthracite	24,139,406	22,172,029	...
Lignite	449,474	430,865	...
Totals	24,588,880	22,602,894	+ 1,985,986

The Production of Pig Iron in France.—The following table shows the distribution of the French blast furnaces : †—

Nord and Pas-de-Calais	12
Meurthe and Moselle	31
Champagne	14
Franche-Comté	2
Centre	7
North-West France	1
Périgord and L'Aveyron	4
Pyrenées and Landes	11
Loire and Rhone	10
Alps	3
South-East France	6
Total	101

This total relates to the year 1887; but the changes since that date have been insignificant.

* *Bulletin du Comité des Forges*, No. 250, pp. 153-158.

† *Stahl und Eisen*, vol. ix. p. 914.

Basic Bessemer Steel in France.—Basic steel is made in France at the following works, the number of converters and their capacity being as under :—

Works.	Number of Converters.	Capacity of Converters.
		Tons.
Joeuf	6	64
Longwy	3	45
Valenciennes	2	20
Creuzot	2	20
Pagny-sur-Meuse	2	20

The last-mentioned works is still in course of construction.*

Imports and Exports.—The French imports and exports † of iron ore, iron, and steel during the years 1889 and 1888 were as follows :—

	Imports.		Exports.	
	1889.	1888.	1889.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,545,363	1,310,695	261,563	294,244
Pig iron	13,344	26,911	120,006	24,540
Manufactured iron	15,288	22,688	67,552	33,383
Steel	4,535	5,243	36,320	14,559

Of iron and steel imported and exported after manufacture, the quantities were as follows :—

	Imports.		Exports.	
	1889.	1888.	1889.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Forge pig iron	51,017	67,035	45,744	64,003
Foundry pig iron	55,570	42,667	54,255	35,655
Charcoal pig iron	4,923	2,367	3,276	1,538
Coke pig iron	4,729	5,219	5,587	5,912
Plates	4,003	3,564	3,922	4,256
Steel	4,769	3,226	9,582	4,068
Totals	125,011	124,078	122,366	115,432

* *Stahl und Eisen*, vol. ix. p. 910.

† *Bulletin du Comité des Forges*, No. 250, p. 127.

VII.—GERMANY.

Pig Iron Statistics.—The following estimate is published * of the production, imports, and exports of pig iron of the German Empire, including Luxemburg, in the year 1889 :—

	Metric Tons.
Production	4,387,504
Imports	354,305
Exports	189,719

The production in 1889 was about 150,000 tons more than it was in 1888. The imports showed a net increase of 164,586 tons.

Progress of the German Iron Industry.—The rapid progress which has been made by the iron industry of the German Empire, including Luxemburg, during recent years, will be seen from the following comparison between the production in the years 1879 and 1888 :†—

	1879.	1888.
	Metric Tons.	Metric Tons.
Iron ore	5,859,439	10,664,307
Pig iron	2,226,587	4,337,121
Iron and steel manufactures . . .	2,189,151	4,371,197

The Coal Trade of Germany.—The imports of coal into Germany in 1889 amounted to 4,537,209 tons, an amount exceeding the imports during 1888 by 1,320,800 tons. This increase was to a certain extent due to a coal strike which lasted for more than a month. The greater portion of the coal imported—some 3,400,000 tons—came from the United Kingdom, Austria-Hungary and Belgium supplying nearly the whole of the remainder.

The quantity of coke imported in 1889 was 387,397 tons, an excess of 118,740 tons over the imports of 1888. The greater portion came from Belgium.

The exports of coal from Germany in 1889 were greatly in excess of the imports, reaching 8,860,217 tons, or 600,060 tons more than in 1888. The coke exported amounted to 814,612 tons, an increase of 13 per cent. over the quantity exported in the previous year.‡

* *Stahl und Eisen*, vol. x. p. 273.

† *Ibid.*, vol. x. p. 67.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 117.

The Duration of Existing Collieries.—In discussing the means by which in the future it may be made possible in Germany to work deposits of coal which at the present time could not be opened up commercially, Triebel * points out that, to take two mines as examples, at the Steinitz colliery in the Saarbrücken district, of the 156 known seams of coal, only 43 are large enough to admit of their being worked at the present time, and at the Gerhard colliery only 11 out of 85. The author considers that it will, at some future date, become necessary to place a duty on coal which will vary in a direct ratio with the ease with which it can be raised; by this means it might be made possible to work thin seams at a commercial advantage. The duty raised in this way should be expended in the form of premiums for the working of the thinner seams.

Imports and Exports.—The following are the official returns† relating to the iron trade imports and exports of the German Customs Union during the year 1889, compared with 1888:—

Description.	Imports.		Exports.	
	1889.	1888.	1889.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,234,842	1,163,373	2,179,563	2,211,820
Pig iron	356,654	225,035	210,566	195,013
Manufactured iron and steel	67,410	48,075	786,753	858,539
Machinery	45,797	42,697	82,393	84,601
Total iron and steel	469,861	315,807	1,079,712	1,138,153

Iron Trade Statistics of Saxony.—The following are the official statistics relating to the production of fuel, iron ore, iron, and steel in the Kingdom of Saxony during the year 1888: ‡—

	Metric Tons.
Coal and anthracite	4,359,085
Coke	79,805
Lignite	839,968
Iron ore	12,349
Manganese ore	329
Foundry pig iron	4,267
Bessemer pig iron	11,405
Forge pig iron	8,498
Castings	55

* *Jahrbuch für Nationalökonomie*, vol. xviii. p. 3.

† *Verein deutscher Eisen- und Stahlindustrieller*, 1890, No. 15.

‡ *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr 1889*.

The workpeople employed at the coal-mines numbered 19,069, and at the lignite mines 2318, as compared with 18,650 and 2324 respectively in the previous year. The fatal accidents in coal-mines numbered thirty-two, and in lignite mines five, as compared with thirty-two and three in 1887. As in 1887, pig iron was produced at only one works, the Königen Marienhütte, Cainsdorf. At this works the pig iron mentioned in the above tabular statement was made with one blast furnace, which worked 52 $\frac{2}{3}$ weeks. The ore charged weighed 57,379 tons.

The mean output for each workman employed in coal-mining was 228 tons, and in lignite-mining 362 tons. The average annual wages per man being respectively £44, 16s. and £27, 19s.

Basic Steel and the Canalisation of the Moselle.—A. Oelwein * discusses the effect of the canalisation of the Moselle on the production of basic steel. The districts of Luxemburg and Lorraine contain inexhaustible beds of phosphoric ore and the minette beds are estimated to contain 2,400,000,000 tons. The Lower Rhine and Westphalia are equally rich in coal. A practicable waterway for vessels of 500 tons burthen would bring into competition the works in the last-named districts and those on the rivers Saar, Lahn, Dill, and Sieg. Of the 6,000,000 tons of ore smelted in Prussia, only 3,500,000 tons came from local sources, whilst the furnaces of Lower Rhine and Westphalia imported nearly three-quarters of a million tons of ore from Spain. The canalisation would induce these latter districts to smelt minette ores.

VIII.—ITALY.

Imports of Iron and Steel.—The imports of iron and steel into Italy † during the years 1889 and 1888 were as follows:—

	1889.	1888.
	Metric Tons.	Metric Tons.
Scrap iron and steel	157,228	164,571
Cast iron	168,677	89,563
Wrought iron and steel—		
Ingots	9,885	20,159
Rolled	70,948	85,624
Sheets	27,405	24,801
Pipes	4,470	4,558
Forged	6,559	4,758
Rails	9,890	33,934
Wrought iron and steel manufactures	22,136	19,774
Steel, hardened	729	833

* *Wochenschrift des österreichischen Ingenieur- und Architekten-Vereins*, 1889, p. 197.

† *Verein deutscher Eisen- und Stahlindustrieller*, 1890, No. 15.

IX.—JAPAN.

Iron Trade Imports.—Dr. H. Reutzsch * quotes from official Japanese statistics relating to the imports of iron into Japan. The value of the imports in the years stated was as follows :—

Years.	Pig Iron.	Rails.	Tools.	Other Hardware.
	Dollars.	Dollars.	Dollars.	Dollars.
1884	88,436	174,998	62,189	1,225,668
1885	105,843	361,497	219,801	1,441,231
1886	101,034	497,816	427,152	1,590,513
1887	118,369	653,534	756,501	1,960,408
1888	397,165	1,462,429	317,371	3,012,204

Production of Coal.—The production of coal in Japan continues to increase rapidly. The official returns for 1888 have just been published, and show that the production for the year was 3,488,629,684 catties (1 catty being equal to 1·3 lb. avoirdupois). Of this quantity 632,440,957 catties were produced from the Miike Mines, and 149,849,861 from those of Kuratsu, both of which are under Government control. The aggregate production of private mines was therefore 2,706,338,866 catties. Compared with 1887 this was an increase of 30 per cent. in the quantity produced.

X.—RUSSIA.

Mineral Statistics of Finland.—According to *Finlands Officiella Statistik*, the raw material of the iron industry consists almost exclusively of lake ore, of which 30,532 tons were obtained in 1887 from 112 lakes. Only one mine yielded a small quantity of iron ore. In the south-west of Finland, Swedish ores are chiefly used. Of these, 20,105 tons were imported and 19,201 tons treated in the blast furnace. The year's production of 20,711 tons of iron was obtained from 52 per cent. of native and 48 per cent. of foreign ores. The aggregate production of the ironworks in 1887 was as follows :—

	Tons.
Pig iron	19,882
Blooms	829
Bar iron	10,398
Ingot iron	2,345
Sheets	395
Nails	1,311

* *Stahl und Eisen*, vol. x. p. 165.

The pig iron was obtained from 15 blast furnaces, the greatest out-turn of a furnace having been 2686·4 tons, and the smallest 244·3 tons. As fuel, 4,951,651 cubic feet of charcoal, and 104,688 cubic feet of wood were employed. The lake ores averaged 35 per cent. of iron, and the Swedish ores 52 per cent.

There were two open-hearth furnaces, which together produced 2344·6 tons of ingot metal, whilst the foundries yielded 2037 tons of castings.

Small open-hearth furnaces are in work at Dahlsbrück and Wärtsilä. In 1887 they produced 60 tons of steel castings, 1910 tons of billets and slabs, 104 tons of sheets, and 2345 tons of ingots. The charge of these furnaces varied from 4·87 to 5·87 tons; and on an average they worked off from 2·2 to 2·4 charges in twenty-four hours. They used per charge as fuel, 300 cubic feet of wood and 21 cubic feet of coal, or 56 cubic feet of wood and 512 cubic feet of peat, together with 0·333 ton of dolomite and 0·520 ton of lime.

Of the 45 existing puddling furnaces, 40 use wood as fuel, and 5 use gas. For each ton of pig iron puddled the fuel consumed amounts to 227 cubic feet of wood or 71 cubic feet of coal.

Forty-one cupolas were at work in 1887, and they produced 2037 tons of castings.

XI.—SPAIN.

Mineral Statistics.—The production of iron ore, coal, iron, and steel in Spain for the year 1888 is stated to be as follows : *—

	Metric Tons.
Iron ore	4,500,000
Coal	1,203,119
Pig iron	232,000
Steel	28,645

Exports of Pig Iron and Iron Ore.—The exports of pig iron and iron ore from Spain in the years 1889 and 1888 were as follows : †—

Description.	1889.	1888.
	Metric Tons.	Metric Tons.
Pig iron	65,471	73,687
Iron ore	5,067,144	4,464,385

* *Revista Minera*, vol. xli.

† *Ibid.*, vol. xli. p. 96.

The imports were as follows :—

Description.	1889.	1888.
	Metric Tons.	Metric Tons.
Coal	1,335,809	1,150,118
Coke	278,743	338,328
Pig iron	27,937	24,403
Cast iron	12,754	11,507
Wrought iron	51,756	22,943
Tin plates	4,228	4,059

XII.—SWEDEN.

Mineral Statistics.—The 435 iron ore mines existing in Sweden in 1888 produced 956,200 tons of ore, added to which 3185 tons of lake iron ore were also won.* These figures show an increase over those of 1887, amounting respectively to 54,000 and 2212 tons. The workpeople employed at the mines numbered 6041, and the 105 steam-engines in use were of 1600 aggregate horse-power. With the exception of the Gellivara, Dannemora, Vigelsbro, and Kopparberg mines, the various iron ore districts show a considerable diminution in the production.

The exports of iron ore from Sweden in 1888 amounted to 117,350 tons, as compared with 41,985 tons in the previous year.

The coal raised in 1888 amounted to 7,460,100 cubic feet—almost identical with the output in 1887. The workpeople employed at the collieries numbered 1201. The imports of coal and coke showed an increase of over 14 per cent. as compared with those of the previous year.

The fireclay raised amounted to 1,981,200 cubic feet.

The 162 active blast furnaces produced 452,450 tons of pig iron, an increase of 450 tons over the production in 1887.

In the various districts the production was as follows :—

	Active Blast Furnaces.	Pig Iron Produced.
		Tons.
Örebro	47	117,385
Kopparberg	33	115,770
Vernland	21	53,380
Gefleborg	18	52,500
Vestmarland	15	43,960

* *Stahl und Eisen*, vol. x. pp. 164-165.

As in previous years, the greatest production of any one works was that of the Domnarfvet Works, with four blast furnaces, which produced 26,336 tons.

The 124 foundries existing in 1888 made 28,250 tons of castings.

The production of blooms amounted to 238,095 tons, the producing works numbering 109. Bar iron, amounting to 253,050 tons, was made at 186 works, possessing 527 hearths and other furnaces; of this quantity of bar iron, 33,315 tons were rolled from Bessemer ingots and 20,025 tons from open-hearth metal. Of the remainder of 199,710 tons representing the quantity of weld iron bars, 5435 tons were produced in twenty-six Walloon hearths, 11,236 tons in ninety-five Franche-Comté hearths, 182,380 tons in 402 Lancashire hearths, and 659 tons in four puddling furnaces.

The number of works employing Bessemer converters has remained stationary—fifteen. The production of Bessemer ingot metal was 68,610 tons in 1888 and 68,200 in 1887.

The open-hearth steelworks, on the other hand, have increased from 19 to 20, the quantity of ingot metal produced having been 44,745 tons in 1888 and 41,900 tons in 1887.

Of other kinds of steel the production was 1206 tons in 1888 as compared with 1470 in the previous year.

The production of iron and steel manufactures increased from 49,250 tons in 1887 to 59,675 in 1888, the active works numbering 144. The sheets produced amounted to 19,700 tons in 1888 and 12,400 tons in 1887.

Open-Hearth Steelworks in Sweden. — E. G. Odelstjerna * shows that the 14 open-hearth steelworks existing in Sweden in 1884 had increased to 20 in 1888, the total number of furnaces having increased from 20 to 29, and the average capacity from 3·5 to 5·1 metric tons. The production of ingots in the former year was 23,699 tons, and in the latter 43,284 tons; the castings produced having weighed 318 tons and 1402 tons respectively.

Some samples of the pig iron used in these furnaces showed the following percentage composition :—

Sample.	C.	Si.	P.	S.	Mn.
I. . . .	3·70	1·31	0·34	0·010	1·15
II. . . .	3·89	0·59	0·30	0·010	1·15
III. . . .	3·70	1·75	0·38	0·018	2·95

* *Jernkontorets Annaler*, 1889, Part VI.

Treated by the ore process, these pig irons yielded a product, one sample of which showed—

C.	Si.	P.	S.	Mn.
0·10	0·02	0·032	0·015	0·25

The Timansberg ore used as an addition contained 59 per cent. of iron ; the percentage of iron reduced from this ore in the furnace was 29·7 of the total quantity of metal contained in it. Similarly, when producing from the same ore and pig iron a metal containing 0·2 per cent. of carbon, the percentage of iron reduced from the ore amounted to 29·2. This yield was much higher when a high carbon steel was being made. Thus, when making a metal having the composition—

C.	Si.	P.	S.	Mn.
0·90	0·20	0·031	0·016	0·25

the yield of iron from the ore amounted to 62·7 per cent. of the total percentage contained in it. The percentage reduction is, however, evidently dependent on the character of the ore used. Thus, when making a low carbon metal having the following composition—

C.	Si.	P.	S.	Mn.
0·15	0·03	0·033	0·014	0·25

the ore from the Åsgrufve gave up 54·1 per cent. of its total. The size of the furnace and other conditions largely influence the result.

A comparison shows that the best results are obtained when the furnace is worked with its full charge, and the ore added in charges large enough to enable the metal to be worked off as quickly as possible. As to the loss of metal which takes place in the open-hearth process, it varies between 4·04 and 6·57 per cent. in the case of soft iron, and is only about 3·2 per cent. when hard steel is being produced.

Iron Trade Exports.—The exports from Sweden during 1889 and 1888 were as follows :—

	1889.	1888.
	Tons.	Tons.
Iron ore.	118,573	117,350
Pig iron.	76,175	49,095
Cast iron	8,530	6,459
Blooms	15,596	14,536
Manufactured iron	200,244	187,775
Bar iron	5,924	3,033
Wire	4,166	1,942
Sheets	5,715	5,780
Nails	2,167	2,381

XIII.—UNITED STATES.

Production of Pig Iron.—The production of pig iron in the United States in 1889 is stated by Mr. J. M. Swank * to have been as follows :—

Fuel Used.	Second Half, 1889.	First Half, 1889.	Total, 1889.
	Pig Iron. Tons of 2000 lbs.	Pig Iron. Tons of 2000 lbs.	Pig Iron. Tons of 2000 lbs.
Anthracite . . .	918,611	1,001,743	1,920,354
Charcoal . . .	306,780	337,520	644,300
Bituminous . . .	2,876,593	3,075,821	5,952,414
Totals . . .	4,101,984	4,415,084	8,517,068

The stocks decreased from 563,286 tons at Midsummer to 277,401 tons at the close of the year.

Of the several States, Pennsylvania shows the largest increase, Alabama being the next in order, the increase over the production of 1888 being respectively 592,056 and 341,933 tons of 2000 lbs. The rapid progress made by the Southern States will be seen from the following table :—

States.	1886.	1887.	1888.	1889.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.
Alabama	283,859	292,762	449,492	791,425
Tennessee	199,166	250,344	267,931	294,655
Virginia	156,250	175,715	197,396	251,356
West Virginia	98,618	82,311	95,259	117,900
Kentucky	54,844	41,907	56,790	42,518
Georgia	46,490	40,947	39,397	27,559
Maryland	30,502	37,427	17,606	33,847
Texas	3,250	4,383	6,587	4,544
North Carolina	2,200	3,640	2,400	2,898
Totals	875,179	929,436	1,132,858	1,566,702

The Iron and Steel Works of the United States.—In the edition of the "Directory to the Iron and Steel Works of the United States" for the present year, published by the American Iron and

* *Bulletin of the American Iron and Steel Association*

Steel Association, Mr. Swank enumerates 575 completed blast furnaces, with an aggregate capacity of 13,168,233 tons of 2000 lbs.; 445 rolling-mills, with 4914 puddling furnaces, 2733 heating furnaces, and 1510 trains of rolls, the aggregate capacity being estimated at 9,215,000 tons of finished iron and steel. In November 1889 there were 41 Bessemer steelworks, with 88 converters, and a capacity of 5,600,000 tons; 14 Clapp-Griffiths converters, with a capacity of 200,000 tons, and 11 Robert converters built and 3 building. The number of open-hearth furnaces is 116, with 23 building, the capacity of the former being estimated at 1,000,000 tons of ingots, and of the latter at 200,000 tons; 43 crucible steelworks contained 3378 pots in November 1889, and three, with 150 pots, were building.

Production of Steel Rails.—The reports received from the various works by the American Iron and Steel Association show that the total quantity of Bessemer steel rails made in the United States in 1889 by works producing their own ingots was 1,468,066 tons, a gain of 102,145 tons over the production in 1888.

In the following table are presented the details of the production of Bessemer steel rails in the United States in 1889. The comparatively small quantity of rails rolled in iron rolling-mills from purchased blooms is not included in this table : *—

States.	First Half, 1889.	Second Half, 1889.	Total, 1889.
	Tons of 2000 lbs.	Tons of 2000 lbs.	Tons of 2000 lbs.
Pennsylvania	523,882	578,635	1,102,517
Illinois	179,201	340,853	520,054
Other States	16,489	5,174	21,663
Totals, 1889	719,572	924,662	1,644,234
Totals, 1888	775,261	754,571	1,529,832

Imports and Exports during 1889.—The following tables are published by the United States Bureau of Statistics, and show the iron trade imports and exports of the United States during the year 1889 :—

* *Iron Age*, vol. xlv. p. 288.

I.—Imports of Iron and Steel.

	Quantities, 12 months ending December 31.		Values, 12 months ending December 31.	
	1889.	1888.	1889.	1888.
	Tons.	Tons.	Dollars.	Dollars.
Iron ore	853,572	587,470	1,852,392	1,313,589
Pig iron	142,230	197,237	2,863,137	3,007,327
Scrap, fit only to be manufactured :				
Iron, wrought and cast	35,917	44,799	447,492	531,365
Steel	2,241	9,179	33,964	113,168
Bar iron, rolled or hammered	29,569	31,744	1,097,132	1,119,107
Bars, railway :				
Of iron	14	21	229	496
Of steel or in part of steel	6,202	63,016	163,110	1,524,662
Cotton ties or hoops, for baling purposes, of iron and steel	20,818	30,205	630,950	837,750
Hoop, band, and scroll iron	7	166	291	7,042
Hoops, bands, strips, sheets and plates of steel	14,014	23,411	783,215	900,218
Ingot, blooms, slabs, billets and bars of steel, and steel in forms not elsewhere specified	72,361	103,577	1,989,837	2,822,870
Sheet, plate, and taggers iron	7,032	6,257	444,456	395,140
Tin plates, terne plates, or taggers tin	331,312	298,237	21,726,707	19,762,961
Wire rods (rivet, screw, nail, and fence), round, in coils and loops, of iron or steel	73,768	101,813	2,412,278	3,127,876
Wire, and wire rope and strand, iron or steel	4,093	3,169	728,197	579,178
Manufactures of, not elsewhere specified :				
Anvils, axles, and forgings of iron or steel	1,399	1,177	179,254	170,016
Chains of iron or steel	621	829	77,618	94,947
Cutlery . . . . .	...	...	2,362,582	2,239,385
Files, file blanks, rasps, and floats . . . . .	...	...	69,155	62,864
Firearms . . . . .	...	...	1,232,796	1,055,071
Machinery . . . . .	...	...	2,829,633	1,966,839
Needles . . . . .	...	...	279,244	284,000
All other . . . . .	...	...	1,676,069	1,709,407
Total, not including iron ore . . . . .	...	...	42,027,296	42,311,689

II.—*Exports of Iron and Steel.*

	Quantities, 12 months ending December 31.		Values, 12 months ending December 31.	
	1889.	1888.	1889.	1888.
	Tons.	Tons.	Dollars.	Dollars.
Iron ore . . . . .	...	133	...	532
Pig iron	13,573	14,364	227,048	256,563
Band, hoop, and scroll iron	13	35	993	2,819
Bar iron	779	586	52,341	40,749
Car wheels No.	11,390	10,194	101,162	91,328
Castings, not elsewhere specified . .	...	...	432,396	327,582
Cutlery . . . . .	...	...	105,245	99,556
Firearms . . . . .	...	...	909,229	608,541
Ingots, bars and rods of steel . . .	45	243	5,707	25,844
Locks, hinges, and other builders' hardware	...	...	1,838,615	1,541,462
Machinery, not elsewhere specified . .	...	...	8,222,904	6,672,094
Nails and spikes :				
Cut	5,266	5,429	282,458	312,629
Wire, wrought, horseshoe, and all other, including tacks	856	599	169,313	136,600
Plates and sheets :				
Of iron	326	2,149	28,547	196,659
Of steel	43	35	4,173	3,905
Printing presses and parts of . . . .	...	...	277,800	180,514
Railroad bars or rails :				
Of iron	1,082	8	30,340	325
Of steel	8,239	6,900	279,420	231,677
Saws and tools . . . . .	...	...	1,975,131	1,912,425
Scales and balances . . . . .	...	...	335,456	330,526
Sewing machines, and parts of . . . .	...	...	2,575,539	2,092,053
Steam engines, and parts of :				
Fire engines No.	7	6	10,939	9,975
Locomotive engines No.	187	67	1,586,746	550,709
Stationary engines No.	269	266	205,407	165,384
Boilers and parts of engines . . . .	...	...	422,223	228,235
Stoves and ranges, and parts of . . . .	...	...	274,739	257,717
Wire	8,655	6,451	679,969	528,359
All other manufactures of iron and steel	...	...	2,678,974	2,774,260
Total, not including iron ore . . . .	...	...	23,712,814	19,578,489

Condition of the Blast Furnaces.—At January 1, 1890, there were in blast in the United States 333 blast furnaces with a weekly capacity of 174,038 tons. The following table shows the condition of the blast furnaces using coke as fuel at the date mentioned : *—

* *Iron Age*, vol. xlv. p. 99.

Coke Furnaces.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number Out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	4	3	2,869	1	1,172
Pennsylvania—					
Pittsburgh District . .	20	19	23,637	1	1,575
Spiegeleisen	1	1	672	...	...
Shenango Valley	19	15	10,983	4	2,259
Juniata and Conemaugh Valleys }	17	11	5,545	6	2,510
Spiegeleisen	1	...	...	1	500
Youghioghaney Valley .	5	4	2,133	1	195
Miscellaneous	4	4	2,602	...	...
Maryland	2	2	1,960	...	...
West Virginia	6	3	1,755	3	1,256
Ohio—					
Mahoning Valley	15	13	11,084	2	1,529
Central and Northern . .	18	15	11,353	3	1,700
Hocking Valley	15	6	1,794	9	1,870
Hanging Rock	14	6	1,259	8	1,480
Indiana	2	2	370	...	...
Illinois	13	10	11,253	3	3,036
Wisconsin	4	4	2,465	...	...
Missouri	5	2	913	3	1,273
Colorado	2	1	534	1	475
The South—					
Virginia	13	11	5,798	2	1,100
Kentucky	4	3	854	1	310
Alabama	28	24	14,618	4	1,765
Tennessee	11	10	4,945	1	500
Georgia	2	...	...	2	890
Totals	225	169	119,396	56	25,395

The following tables show the condition of the anthracite and charcoal furnaces at the same date:—

Anthracite Furnaces.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number Out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	23	11	4,014	12	3,154
New Jersey	14	5	2,313	9	3,285
Spiegeleisen	3	3	229	...	...
Pennsylvania—					
Lehigh Valley	46	33	12,616	13	3,662
Spiegeleisen	1	1	57	...	...
Schuylkill Valley	37	17	7,251	20	5,270
U. Susquehanna Valley . .	17	11	4,118	6	1,407
Lebanon Valley	16	14	7,024	2	522
L. Susquehanna Valley . .	18	10	5,235	8	2,030
Totals	175	105	42,857	70	19,330

Charcoal Furnaces.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number Out of Blast.	Capacity per Week.
			Tons.		Tons.
New England	14	7	610	7	480
New York	8	3	361	5	523
Pennsylvania	16	6	385	10	649
Maryland	6	2	246	4	380
Virginia	18	3	145	15	716
West Virginia	3	...	...	3	165
Ohio	11	7	424	4	198
Kentucky	2	2	196	...	...
North Carolina	2	1	70	1	70
Tennessee	7	3	801	4	443
Georgia	1	1	181	...	...
Alabama	13	8	2,158	5	885
Michigan	23	11	3,766	12	3,658
Missouri	2	2	582	...	...
Wisconsin	6	3	1,560	3	710
Texas	1	...	...	1	173
California	1	...	...	1	120
Washington	1	...	...	1	192
Oregon	1	...	...	1	190
Totals	136	59	11,485	77	9,552

Exports of Petroleum.—The exports of petroleum from the United States in 1889 showed a considerable increase over those of 1888. The exports were as follows : *—

	1889.	1888.
Refined	376,073	321,508
Crude	54,633	44,792
Naphtha	11,593	7,654

Production of Lake Superior Ore.—The production of iron ore in the Lake Superior district during 1889 showed an increase of 50 per cent. over the output of the previous year. The various districts are estimated to have produced the following amounts : †—

	Tons.
Marquette Range	2,523,041
Menominee Range	1,684,618
Gogebic Range	1,782,810
Vermilion Range	819,639
Total	6,810,108

* *Iron Age*, vol. xlv. p. 180.

† *Journal of the United States Association of Charcoal Iron Workers*, vol. v. pp. 317-322.

In round numbers, 80 per cent. of the total shipments were sent to ports on the south shore of Lake Erie, the remainder going to Chicago and the shores of Lake Michigan. Eighteen mines produced more than 100,000 tons each in 1889, and, out of the ninety-five active mines, these eighteen gave 66 per cent. of the total production.

	Tons.
1. Norrie Mine, Gogebic Range	561,145
2. Minnesota Iron Company, Vermilion Range	513,295
3. Chapin Mine, Menominee Range	503,289
4. Chandler Mine, Vermilion Range	303,200
5. Lake Superior Mine, Marquette Range	274,579
6. Republic Mine, Marquette Range	264,584
7. Cleveland Mine, Marquette Range	262,835
8. Pittsburgh and Lake Angeline, Marquette Range	228,614
9. Ashland Mine, Gogebic Range	221,274
10. Champion Mine, Marquette Range	206,754
11. Aurora Mine, Gogebic Range	196,732
12. Florence Mine, Menominee Range	180,642
13. Iron River, Menominee Range	173,525
14. Vulcan Mine, Menominee Range	153,556
15. Dunn Mine, Menominee Range	148,320
16. Cliffs Shaft, Marquette Range	126,627
17. Ludington Mine, Menominee Range	106,974
18. Germania Mine, Gogebic Range	101,717
Total	4,527,662

The Vermilion Iron Ore Range.—The export of iron ore from the Vermilion Range has steadily increased from 62,124 tons in 1884 to 836,198 tons in 1889, the total for this period amounting to 2,322,286 tons. Up to 1889 only one mine was exporting ore, that of the Minnesota Iron Company, the ore containing about 68 per cent. of iron. The ore found throughout the range is, with but few exceptions, a hard Bessemer ore; large bodies of soft Bessemer ore being of occasional occurrence. The range is being rapidly opened up.*

Iron Industry in the South United States.—In the States of Virginia, Kentucky, Alabama, Tennessee, and Georgia there are 60 coke blast furnaces, of which 46 with a capacity of 25,480 tons per week are in blast, and 14 with a capacity of 6269 out of blast. In the same States, with the addition of North Carolina and Texas, there are 49 charcoal furnaces, of which 23 are in blast with a capacity of 3832 tons weekly, and 26 with a capacity of 1644 tons are out of blast. The total for the United States is 226 coke furnaces, of which 160 are in blast, and 154 charcoal furnaces with 67 in blast. The estimated production of

* The St. Paul *Pioneer Press*, through *Iron Age*, vol. xiv. p. 92.

the above seven States is 1,396,903 tons of pig iron, of which Alabama produced 785,521 tons. In 1888 the total production was 1,018,043 tons, and it has steadily increased since 1880. The ore production has also steadily increased since 1886 up to 3,000,000 tons in 1889. About 70 per cent. of this is red hæmatite or fossil ore. But little has yet been done in these States with regard to steel.*

Iron Manufacture in Illinois.—The Illinois Steel Company used during the year 1889, 775,000 tons of ore, 575,000 tons of coke, 140,000 tons of coal, and 200,000 tons of limestone. The production included: pig iron, 572,095 tons; rails, 461,147 tons; wire, 43,488 tons; merchant bar and nails, 60,230 tons; billets, 50,289 tons, spiegeleisen and ferro-manganese, 18,031 tons; and beams and slabs, 4030 tons.†

Production of Coke in the Connellsville District.—The *Connellsville Courier* ‡ estimates the production of coke in the Connellsville district in 1889 at 5,825,826 tons. The output for 1888 amounted to about 5,000,000 tons.

Petroleum in Pennsylvania.—The production of petroleum in Washington County, Pennsylvania, amounted in 1889 to 4,015,000 barrels. The wells bored during the year numbered 576, the cost of boring being 4,000,000 dollars. §

Production of Coal in Illinois.—The official returns relating to the production of coal in Illinois for the fiscal year 1888–89 are as follows:—

	1889.	1888.
Number of tons of lump-coal mined	11,597,963	11,855,188
Aggregate value of product at the mine . . . dollars	12,496,885	13,309,030
Average value per ton at the mines	1·0775	1·123
Number of employees of all kinds	30,526	29,410
Number of miners	23,583	23,648
Number of other employees (including boys)	6,943	5,762
Number of boys employed under-ground	859	868
Average price paid per ton for hand-mining . . dollars	0·731	0·716
Number of men killed	42	55
Number of mining machines in use	235	272

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 333–335.

† *Iron Age*, vol. xlv. p. 13.

‡ Through *Iron Age*, vol. xlv. p. 224.

§ *Iron Age*, vol. xlv. p. 175.

The total fuel product, including what goes through as well as over the screens, for 1888 was 13,396,362 tons, and for 1889, 13,105,698 tons.

The average daily wages paid to machine-men indicate ruling rates of $2\frac{1}{4}$ dollars and $2\frac{1}{2}$ dollars per day for machine operators, $1\frac{3}{4}$ dollar for helpers, 2 dollars for blasters, $1\frac{3}{4}$ dollar for loaders, 2 dollars for timber-men, $1\frac{1}{2}$ dollar and $1\frac{3}{4}$ dollar for labourers, and 2 dollars for drillers. The average price paid for mining by hand decreased from 80 cents per ton in 1883 to 73 cents in 1889, though in 1886 the average was as low as $67\frac{1}{2}$ cents. These are general averages by districts. The extremes show the lowest to be $31\frac{1}{2}$ cents, and the highest $1\frac{1}{2}$ dollar. The price paid for the greater portion of hand-mining is from 50 cents to 95 cents per ton, the latter in the thin coal of Will and Grundy Counties, and the former in the dry seams of the Southern fields.

This year the machine-mined coal is 21 per cent. of the entire product; last year it was 19 per cent. The increase in the output of this character is largely in the fourth district, and the decline in the first and fifth districts. Several new machines have been produced during the year, and experiments have been made in connection with the use of electricity in the place of compressed air. The mine at Girard, in Macoupin County, has an electric plant on trial, which is furnishing motive-power to a new device for under-cutting the coal, and at the same time furnishing a current for a system of electric light throughout the workings.*

XIV.—COMPARATIVE TABLES.

The Statistics of Iron.—Dr. H. Wedding,† at the request of the Council of the German Iron and Steel Institute, has collated the known statistics relating to the production of iron ore, and the manufacture from it of iron and steel.

Iron Ore.—The total production of iron ore in the world amounts annually to over 50 millions of tons, the production having increased from 2 millions of tons in 1800 to nearly 11 millions in 1850, 28 millions in 1870, 43 millions in 1880, and over 51 millions in 1888, more than four-fifths of this latter total having been derived from the United Kingdom, United States, Germany, and France.

* *Iron Age*, vol. xlv. p. 54.

† *Stahl und Eisen*, vol. x. pp. 160-163, 268-271, 368-372, &c.

Spain, Algeria, Italy, Cuba, Greece, Portugal, and Asia Minor are ore-exporting countries. Germany, Belgium, France, Austria-Hungary, Sweden, and Canada also export considerable quantities of iron ore, but they treat the larger quantity of their own ore themselves, whilst Germany, Belgium, and France import considerable quantities, and the imports into Belgium are about nine times as large as the production of that country. Great Britain and the United States import largely, but have no appreciable exports of iron ore.

The author estimates the annual quantities of ore available for smelting purposes at the following amounts:—

	Tons.
United Kingdom	18,433,000
United States	12,618,000
Germany	9,616,000
France	3,602,000
Belgium	1,779,000
Austria-Hungary	1,483,000

The average value of the ton of ore is about 4s. 9d.

Progress of the Basic Bessemer Process.—The total make of steel and ingot iron by the basic process during 1889 shows an increase over the previous year of 321,318 tons. The total production from the introduction of this process up to date is 10,845,000 tons. The production by countries is as follows:—

Countries.	1889.		1888.	
	Total.	With under 0·17 per cent. Carbon.	Total.	With under 0·17 per cent. Carbon.
	Tons.	Tons.	Tons.	Tons.
England	493,919	348,828	408,594	276,476
Germany, Luxemburg, and Austria	1,481,642	1,185,323	1,276,070	1,026,033
France	222,392	159,271	222,333	158,223
Belgium and other countries	76,599	71,217	46,237	32,300
Totals	2,274,552	1,764,639	1,953,234	1,493,032

With this about 700,000 tons of slag, containing about 36 per cent. of calcium phosphate, were produced, and mostly used as a fertiliser.

Comparative Iron Trade Exports.—In connection with the recent Pan-American Congress, the United States Bureau of Statistics has issued * the following comparative table of iron trade exports:—

* *Iron Age*, vol. xlv. p. 222.

Exports of Iron and Steel.

	From United States.	From Great Britain.	From France.	From Germany.	From Spain.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
To Mexico	1,946,948	1,050,804	149,382	118,048	48,978
„ Central American States .	879,020	676,906	4,102	...	...
„ Spanish West Indies .	1,332,962	1,525,599	36,395	129,234	105,203
„ United States of Colombia	710,492	553,686	329,895	...	30,953
„ Venezuela	404,402	500,841	19,181	...	...
„ Brazil	679,252	4,998,246	507,029	633,794	...
„ Uruguay	143,898	1,503,515	144,061	...	...
„ Argentine Republic . .	740,680	8,524,065	995,990	1,825,460	18,398
„ Chili	491,586	2,093,071	143,333	224,672	...
„ Peru	120,849	591,431	28,189	23,324	...
Totals	7,450,089*	22,018,164†	2,357,557	2,954,532	203,532

The figures given for the United States cover the fiscal year ending June 30, 1888, whilst those for the United Kingdom, France and Spain are for the calendar year 1887, and those for Germany for the year ending March 31, 1887.

* 7,452,089 in original.

† 21,998,164 in original.

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